DESIGN ANALYSIS DRAFT FINAL

BOARHEAD FARMS SUPERFUND SITE GROUNDWATER TREATMENT PLANT

RAPID RESPONSE DESIGN PACKAGE

UPPER BLACK EDDY, PA

JUNE 1996

**US Army Corps
of Engineers**
Omaha District

OMAHA DISTRICT

FINAL DRAFT
DESIGN ANALYSIS

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PART-1   GENERAL DESCRIPTION

1.   **PURPOSE.**   The purpose of the groudwater facility for Boarhead Farms Superfund Site is to provide treatment of groundwater pumped from eight (8) existing wells and a new collection trench.   The effluent will be treated to meet the State of Pennsylvania Water Quality Criteria established by the attached record of conversations and memorandums.

2.   **AUTHORIZATION AND SCOPE.**

   2.1.   **AUTHORITY.** The project was authorized by Interagency Agreement with the United States Environmental Protection Agency, Region III.   The EPA IAG number is xxxxxx.

   2.2.   **SCOPE.** The implementation of a non-time critical removal action at the Boarhead Farms Superfund Site in Upper Black Eddy, Pennsylvania.   The new facility is designed for a gross area of 2,400 square feet.

3.   **APPLICABLE CRITERIA.**

   National Fire Protection Association (NFPA 101, Life Safety Code)

   Uniform Building Code,   Latest Edition.

   Uniform Electric Code, Latest Edition.

   Omaha District, Corps of Engineers, Design Guide.

   Final Engineering Evaluation / Cost Analysis dated June 1995.

   Action Memorandum signed March 1996 by US EPA Region III Director.

4.   **PROJECT DESCRIPTION.** The purpose of the groundwater treatment system is to collect and treat contaminated groundwater. The contaminants of concern include metals; such as cadmium and volatile organics compounds (VOC); such as trichloroethylene.   The Boarhead Farms Groundwater Treatment Facility shall operate as described below to achieve the contaminant removal effluent requirements.   The system has been divided into five main systems, i.e.,   (1) Groundwater extraction and storage, (2)Water Treatment - Metals Removal by Chemical Precipitation, (3) Sludge Handling, (4) Water Treatment - VOC Removal by Air Stripping/GAC, and (5) Misc Items.

PART - 2   DESIGN REQUIREMENTS AND PROVISIONS

1.   TRENCH/DRAIN GROUNDWATER FLOW DESIGN ANALYSIS

1.1.   Introduction. Groundwater extraction for treatment at the Boarhead Farms Superfund Site will consist of 8 extraction wells (EW-6, 8, 9, 10, 11, 13, 15, and 17) and a trench/drain of approximately 1300 feet in length. Based on USGS pump tests, the eight extraction wells selected have a combined 8 hr. sustainable yield of approximately 25 to 30 GPM. Extraction well EW-2 was initially included in the extraction system but review of documents indicated this extraction well has been previously abandoned.

This design analysis is being performed to provide a preliminary estimate of the anticipated groundwater production from the trench/drain, so that treatment system influent on a gallons per minute and a 24 hour basis may be ascertained for design of the ground water treatment system. Calculations are made for anticipated peak sustained groundwater/trench flow (moderately conservative) which are associated with high water table conditions during wettest times of the year (Dec.- April) at the site.

At the time of this design analysis, extraction well boring logs located in the vicinity of the proposed trench were not available for review, so site geologic and stratigraphic data and slug test data from monitoring wells (CH2M-Hill RI Report) was used and are the basis of the following assumptions. Where possible, these assumptions (moderately conservative) will be field checked during the Pre-Design sampling effort. The ARCs contractor, CH2M-Hill has also been contacted to obtain the additional extraction well data (boring logs, pump test details etc.).

1.2.   FLOW ASSUMPTIONS.

ASSUMPTIONS

Typical Trench Profile.

Overburden Material	Depth	Avg. Thickness	Range	K value
1) Silt and Clay	Surface	3'	0 to 5'	0.0082 ft/day
2) Saprolite	3'	3'	0 to 8'	9.6 ft/day
3) Weathered Diabase	6'	2'	0 to 4'	9.6 ft/day
Bedrock				
1)"Competent Diabase" (upper fractured interval)	8'	40'	30 to 50'	N/A

1.2.1.   Transmissivity. The transmissivity (T=Kb) of the trench (up gradient) seepage face is the principal factor that controls ground water discharge to the trench. It is assumed seepage across the down gradient trench face may be ignored after initial flow conditions reach equilibrium (i.e. become or approach zero flow) due to the proximity of down gradient extraction wells, relatively steep hydraulic gradient in the area, and cutoff of ground water recharge from up gradient areas by the trench. These factors are expected to

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significantly lower the water table down gradient of the trench such that the down gradient seepage face boundary becomes essentially zero flow.

The southern portion of the trench is nearest two (2) ponds located immediately down- and side-gradient. This is an area where the above assumption (ignoring seepage from down gradient) may not apply. Depending on the local topography, water levels maintained in the ponds, the local saturated thickness and hydraulic conductivity of the overburden, and any hydraulic gradient established between the trench and the pond in this area, significant flow from the pond to the trench may be possible. Due to the number of unknowns, ground water seepage from the trench to the pond is not considered here.

1.2.2. **Collection Trench Assumptions.** The length of the trench is approximately 1300 feet. Much of the trench length is parallel or subparallel to the groundwater flow direction. To account for this, a length (L_p) of 1000 feet is used in the calculation as a more representative length perpendicular to groundwater flow.

1.2.2.1. **Depth.** The depth of trench is limited by the depth competent bedrock is encountered. This occurs at the base of the weathered diabase/top of competent diabase where split spoon or auger refusal is reported in boring logs and is believed to average approximately 8 feet in depth in the trench area. It is assumed excavation is possible to the base of the weathered diabase.

1.2.3. **Saturated Thickness.** The average saturated thickness under highest water table conditions is the interval taken from a depth of 1 foot below the land surface to the top of the competent bedrock (8' depth) or 7 feet. It is assumed that excavation to the top of the competent diabase (bedrock) is possible throughout the trench extent. Five (5) feet is assumed to be the average saturated thickness (h) of non-clay or more hydraulically conductive overburden materials (saprolite and weathered diabase). Thus, a 5 foot saturated interval thickness representative of the more hydraulically conductive overburden materials was selected for use in the calculation due to the variation in thickness of clay and variable depth to bedrock. Hydraulic conductivity of the clay material based on percolation tests (K = 0.0082 ft./day), suggest no significant yield to the trench is likely when this overburden material is saturated.

1.2.4. **Hydraulic Conductivity.** The hydraulic conductivity of the overburden material is the average value (K = 9.6 ft./day) reported in the RI based on slug testing of three (3) overburden wells (MW-4, -5, and -15). This value is representative of the combined hydraulic properties of the saprolite and weathered diabase (fractured or jointed) bedrock.

1.2.5. **Hydraulic Gradient.** The average hydraulic gradient in the trench area is that reported in the RI for the area between ground water contour line 570 and 555 (12/03/94). This is a gradient of 0.0894 ft./ft..

1.2.6. **Flow Patterns.** No significant upward (vertical) flow occurs (via fractures) from the competent diabase bedrock to the overburden material at the base of the trench.

1.2.7. **Surface Interconnection.** No surface water entry to the collection system via the trench cover.

1.3. **Flow Calculations.**

Given the above assumptions, discharge across the up gradient seepage face of the trench under high water table conditions is expected to provide a somewhat conservative yield or flow for the trench collection system. It is found by:

$$Q = -K \times h \times dh/dx \times L_p \times 1 \text{ day}/1440 \text{ min.} \times 7.48 \text{ gal/ft}^3$$

where Q is the discharge in GPM
K is the average hydraulic conductivity of the overburden (9.6 ft./day)
h is the average height of the seepage face (5 ft.)
dh/dx is the water table gradient (0.0894 ft./ft.)
L_p is the length of the trench perpendicular to ground water flow

then Q = 9.6'/day x 5' x 0.0894 x 1000' x 1 day/1440 min. x 7.48 gal/ft.³

Q = <u>22.3 GPM</u>

Based on the previous assumptions, it is anticipated that a 50 to 55 GPM "peak sustained flow" from both the extraction wells and the trench/drain to the treatment system should be anticipated during high water table conditions (Dec. to April).

A second calculation using a more conservative approach using the following parameter values resulted in a trench collection system flow/yield of 48 GPM:

maximum K value from slug tests = 11.4 ft./day
full trench length . = 1300 ft.
seepage face height = 8 ft.

.The pre-design sampling effort may indicate one or more of these more conservative values are more representative. This could be due to a greater average depth to bedrock and/or saturated saprolite/weathered bedrock thickness encountered in the trench area (less clay) or a field based decision to extend the trench length. Relative water elevations between the ponds and the bottom of nearby portions of the trench should also be noted as this could effect flow to the trench from down gradient. The trench collection system would then be expected to provide greater flow to the treatment system. Greater system storage capacity coupled with longer hours of operation on a daily basis built into the design could possibly provide the flexibility to handle this increased flow however.

Alternatively, shallower bedrock or excavation depth and thicker clay/silt intervals found to characterize the trench area would be expected to reduce yield of the trench collection system. Another significant unknown is the extent of

recharge to the ground water system once the extraction system has reached equilibrium and how the local groundwater budget is impacted by the extraction system over time. Whether or not surface recharge (given the slope and clay surface soils) combined with ground water flow from up gradient is sufficient to maintain flow to the trench during dry periods, or sufficient to cause the water table to rebound fully during wet periods is unknown. Thus, mining of the ground water over a few years could result in sufficient lowering of the water table so that the trench system flows are significantly reduced.

2. WATER AND WASTEWATER REQUIREMENTS.

2.1. **CRITERIA.** The following criteria applies to this project.

Water Supply, Treatment and Distribution.

National Standard Plumbing Code - 1993.

Applicable local, state and federal regulatory requirements.

Environmental, Sanitary and Industrial Wastewater Systems.

Pennsylvania Title 25 Part 1, Subpart A, Chapter 16, Water Quality Toxic Management, Appendix A, Table 1, Water Quality Criteria for Toxic Substances.

Clean Water Act.

Resource Conservation and Recovery Act.

Applicable local, state and federal regulatory requirements.

2.2. **TECHNOLOGY EVALUATION.** Reference the Appendix for the Technology Evaluation and Engineering Estimate. Chemical Precipitation with sludge handling followed by air stripping with liquid phase GAC as effluent polishing was recommended as follows:

a. The treatment train provides flexibility in modifying the system, chemical precipitation is known to be an effective treatment process, with high performance in treating varying influent concentrations and flowrates.

b. The treatment train has an estimated 16 hours per week O&M requirement. O&M labor costs is cheaper than ion exchange regenerations costs. One ion exchange changeout costs approximately $4500 which corresponds to 90 operator hours at $50 per hour.

c. The treatment train is most economical based on estimated from discussions with vendors.

2.3. **POTABLE WATER SUPPLY.** Potable water will not be provided under this project.

2.4. **NON-POTABLE WATER SUPPLY.** Non-potable water will be supplied to the process bay hose bib system and individual processes requiring a non-potable water supply. The non-potable water supply will be provided by a hydropneumatic tank located in the building.

2.5.   **WASTEWATER (DOMESTIC)**.   No lavatories or toilets will be provided under this project, therefore no domestic wastewater will be generated.   All water collected in the building trench drain system will be recycled through the treatment process.

2.6.   **INFLUENT CONCENTRATIONS AND EFFLUENT REQUIREMENTS**.   The Remedial Investigation (RI) does not specify any listed wastes present at the site.   The following is a table of the influent concentrations and effluent requirements specified by the State of Pennsylvania

Treatment Requirements for Volatile Organics Boarhead Farms Upper Black Eddy, PA		
Compound	Expected Influent Quality (mg/L) (A)	Effluent Requirements (mg/L) (B)
Acetone	.01	3.7
Chloromethane	.004	monitor
EthylBenzene	.004	0.7
Methylene Chloride	.02	0.005
1,1-DiChloroEthene	.03	0.007
1,1-DiChloroEthane	.05	0.810
cis-1,2-DiChloroEthene	.25	0.07
1,1,1 TriChloroEthane	1	0.2
TriChloroEthylene TCE	6	0.005
Benzene	1	0.005
1,1,2-TriChloroEthane	0.002	monitor
TetraChlorEthene (PCE)	0.15	0.005
Toluene	0.8	1
Vinyl Chloride	0.001	0.002
Xylene	0.01	monitor
Carbon Disulfide	0.002	monitor
2,4-DiChloroPhenol	ND	0.11
CarbonTetraChloride	ND	0.005
Naphthalene	ND	1.5
1,2-DiChlorethane	ND	0.005

(A) Estimate based on weighted average of water quality for extraction wells analyzed during pump tests. No other volatiles or semi-volatiles were detected.

(B) As determined by the Pennsylvania Department of Environmental Resources in June 21, 1994 Memo to Hary Harbold.
(ND) Not detected in any of the wells to be pumped during the interim action.

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Treatment Requirements for Metals Boarhead Farms Upper Black Eddy, PA		
Compound (Total Metals)	Expected Influent Quality (mg/L) (A)	Effluent Requirements mg/L (B)
Aluminum	5.321	monitor
Antimony	0.002	0.006
Arsenic	0.001	monitor
Barium	0.4	monitor
Beryllium	0.001	0.004
Cadmium	0.014	0.005
Calcium	101.8	monitor
Total Chromium	0.1	0.1
Cobalt	0.06	monitor
Copper	0.02	1.0
Iron	37	monitor
Lead	0.003	monitor
Magnesium	44	monitor
Manganese	4	0.05
Mercury	0.001	monitor
Nickel	0.12	0.1
Potassium	2	monitor
Silver	0.001	monitor
Sodium	13	monitor
Thallium	0.001	monitor
Thorium	ND	monitor
Vanadium	0.008	0.1
Zinc	0.03	5
Cyanide	0.011	monitor
Chloride	18	monitor
TDS	690	monitor
Sulfate	400	monitor

Treatment Requirements for Metals Boarhead Farms Upper Black Eddy, PA		
Compound (Total Metals)	Expected Influent Quality (mg/L) (A)	Effluent Requirements mg/L (B)
pH	6.0 - 9.0	6.0 - 9.0
Alkalinity	25	monitor

(A)   Estimate based on weighted average of water quality for extraction wells analyzed during pump tests. No other volatiles or semi-volatiles were detected.

(B)   As determined by the Pennsylvania Department of Environmental Resources in June 21, 1994 Memo to Hary Harbold.

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3. PROCESS DESCRIPTION

3.1. PURPOSE. The purpose of the groundwater treatment system is to collect and treat contaminated groundwater. The contaminants of concern include metals; such as cadmium and volatile organics compounds (VOC); such as trichloroethylene. The Boarhead Farms Groundwater Treatment Facility shall operate as described below to achieve the contaminant removal effluent requirements. The system has been divided into five main systems, i.e., (1) Groundwater extraction and storage, (2)Water Treatment - Metals Removal by Chemical Precipitation, (3) Sludge Handling, (4) Water Treatment - VOC Removal by Air Stripping/GAC, and (5) Misc Items.

3.2. Ground Water Extraction and Storage System

3.2.1. Extraction Well System. Contaminated groundwater shall be extracted from eight (8) existing wells EW-6, EW-8, EW-9, EW-10, EW-11, EW-13, EW-15, and EW-17. The new pneumatic air driven pumps, provided under this contract, will transfer the groundwater to an influent storage tank located in the treatment building. Each extraction well will be equipped with a pitless adapter, a filter/regulator, and a pump cycle counter, with a remote readout in the building, which will determine the flowrate for each well. The cumulative sustained 8-hr flowrate is estimated at 30 gpm from the eight wells.

3.2.2. Collection Trench System. Groundwater shall be collected in a 1,300 lft collection trench. The trench will have more than one sump (well) located at the low points and air dirven pumps will transfer the groundwater to the influent storage tank located inside the building. The estimated cumulative peak flowrate is 20 gpm. **The exact number of sumps will be determined for the Final Design Package.**

3.3. Water Treatment - Metals Removal by Chemical Precipitation. The contaminated water will be transferred by centrifugal pumps into a pre-packaged chemical precipitation unit to remove metals. The chemical precipitation unit will also remove other non-hazardous metal ions; such as iron; because of the potential interference with the downstream VOC's removal process. The water will flow by gravity through the chemical precipitation unit, into a inclined plate clarifier, and into a storage tank.

3.3.1. Chemical Feed System. The pre-packaged chemical precipitation system supplier will recommend the chemical feed system chemicals, feedrate, and necessary equipment. The chemical feed system materials will be compatible with the constituents of concern and with the chemicals used during the process. All chemical storage tanks will have secondary containment.

3.3.2. Inclined Plate Clarifier. The pre-packaged chemical precipitation supplier shall recommend an inclined plate clarifier to use for solids separation. The clarifier shall have an integral sludge storage compartment. The supplier shall recommend the size and operation of air diaphragm sludge pumps that transfer the sludge from the storage compartment to the sludge holding tank.

3.3.3. **Storage Tank.** A storage tank shall be installed, downstream of the clarifier, to temporarily hold the treated groundwater before being pumped through the pressure filters and air stripping system.

3.3.4. **Pressure Filtration.** The Contractor shall install an automatic backwashing three vessel pressure filtration system. The backwash water will be discharged into the building trench drain system. The manufacturer of the filtration system shall provide the size of the feed pumps, the backwash pumps, and the backwash water source, either raw water or effluent water.

3.4. **Sludge Handling.** The sludge handling supplier shall provide the appropriate sized air diaphragm sludge transfer pumps that deliver the sludge from the sludge holding tank to the plate filter press. The sludge holding tank shall be a coned bottom type.

3.4.1. **Plate Filter Press.** The sludge handling supplier shall provide a plate filter press for dewatering the sludge. The press shall operate based on the level switches (LSL-4 & LHL-4) located in the sludge holding tank. When the press is full, the operator must manually activated the filter emptying process. The filtrate shall be drained into the building trench drain system for recycling through the treatment process.

3.4.2. **Filter Cake.** The Contractor shall dispose of the filter cake at the appropriate off-site disposal facility. The filter cake shall be assumed non-hazardous.

3.5. **Water Treatment - VOC Removed by Air Stripping/GAC.** The Contractor shall coordinate between the air stripping supplier and the liquid carbon adsorption suppllier.

3.5.1. **Shallow Tray Aerator.** The shallow tray aerator shall be provided to remove the VOC's to meet the effluent standards based on the provided influent concentrations. The manufacturer of the tray aerator shall verify the sizes and provide the necessary support equipment; such as the blower and discharge pumps. A recycle line shall be provided to allow re-treatment.

3.5.2. **Off- Gas Treatment.** Under this contract off-gas treatment shall not be provided, however space for future Vapor Phase GAC units shall be provided.

3.5.3. **Liquid Carbon Adsorption.** The liquid carbon adsorption system shall be installed to polish the effluent water. The influent concentrations are weighted averages and may vary, therefore the liquid GAC units will ensure that the effluent requirements are met. Under this contract only one liquid GAC unit shall be provided, however space for a second unit shall be provided.

3.6. **Miscellaneous Items.** The following are support items within the treatment facility.

3.6.1.   **Hydropneumatic Tank for Non-Potable Water.** The site does not have a potable water source. The effluent will be used for housekeeping and chemical dilution and mixing purposes. The hydropneumatic tank shall operate between 30 and 50 psi.

3.6.2.   **Effluent and Final pH adjustment Tank.** The discharge pH shall be 6.5 to 7.0. Preceding the storage tank, an in-line static mixer and pH monitor shall provide final pH adjustment before discharge, if necessary.   The effluent tank shall provide the water source for the the hydropneumatic tank. The treated effluent will be surface discharged. The EPA will obtain any permits required.

3.6.3.   **Discharge Location.** The discharge location is within the vicinity as shown on the drawings. The discharge outfall detail shall be approved by the Contracting Officer's Representative (COR). The Contractor shall determine if the discharge will be by gravity or pressure line. The Contractor shall design the discharge pumps, if required.

4.   TREATMENT SYSTEM OPERATION. The recommended treatment system operation may vary, based on individual manufacturer recommendations.

4.1.   GENERAL.   The process treatment system consists of a collection trench pump (CTP-1) and eight (8) extraction wells (EW-6, -8, -9, -10, -11, -13, -15, and -17) to remove contaminated groundwater.   An influent tank (T-1) equalizes the flowrate to operate the treatment facility in a batch mode. The feed pumps (FP-1 & FP-2) transfer the untreated water to a pre-packaged chemical precipitation unit (CP-1) which shall remove hazardous metals and shall pre-treat for non-hazardous metals that may interfere with the VOC treatment, such as iron.   The chemical precipitation unit shall include the chemical feed systems, inclined plate clarifier with storage tank (T-2), and sludge pumps (SP-1 & SP-2) to transfer the sludge from the integral sludge holding compartment in the clarifier to the sludge holding tank (T-3). The pressure filter pumps (PFP-1 & PFP-2) shall transfer the water from the clarifier sump tank (T-2) to the pressure filters (PF-1) before the shallow tray aerator (TA-1). The tray aerator system shall include the blower (B-1) and tray aerator sump discharge pumps (DP-1 & DP-2).   Off-gas treatment will not be provided under this contract, however space will be allocated for the potential off-gas treatment equipment.   The sludge pumps (ADP-1 & ADP-2) shall transfer the sludge from the sludge holding tank (T-3) to the plate filter press (PFP-1) to be dewatered.   In addition, a final pH adjustment/effluent tank (T-4) shall provide treated effluent water to be used for housekeeping, chemical dilution and mixing purposes (by the effluent pump EP-1 and a hydropneumatic tank), and as a backwashing water source (if required by the backwash pumps BW-1 & BW-2) for the pressure filters. The discharge location shall be determined by the Contractor. The effluent discharge pumps (DP-3 & DP-4), may be required, to pump to the discharge location. A building sump and sump pumps (SP-1 & SP-2) shall collect and recycle any discharge water encountered within the facility plus all pressure filter backwash, sludge holding tank decant, and filter press filtrate. A recycle line shall be installed downstream of the tray aerator sump discharge pumps to allow the treated water to be recycled trough the process, if required.

4.2.   EXTRACTION WELLS. The eight (8) existing wells (EW-6, EW-8, EW-9, EW-10, EW-11, EW-13, EW-15, and EW-17) will be retrofitted with a pitless adapter, an automatic air-driven pump, a filter and regulator (REG-6 Typ. of each well), and a pump cycle counter (CYC-6 Typ. of each well). The digital remote readout for the pump cycle counters shall be located in the treatment building. The air driven controlless pump shall sense liquid level internally, running when there's enough to pump, and shutting down automatically when well levels drop too low.   The single-manifolded air supply line shall be equipped with a solenoid valve (SOL-1), that shall close, when the high high level switch (LSHH-1) located in the influent tank (T-1) prevents the operation of the extraction wells.

4.3.   COLLECTION TRENCH PUMP (CTP-1). An automatic air-driven pump, a filter and regulator (REG-X), a pump cycle counter (CYC-X), and a pitless adapter shall be provided. The actual number of sump (Well) locations will be determined by the Final Design Package Submittal. The digital remote readout for the pump cycle counters shall be located in the treatment building.   The air driven controlless pump shall sense liquid level internally, running when there's enough to pump, and shutting down automatically when well levels drop too low.   The

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single-manifolded air supply line shall be equipped with a solenoid valve (SOL-2), that shall close, when the high high level switch (LSHH-1) located in the influent tank (T-1) prevents the operation of the extraction wells.

4.4.   FEED PUMPS (FP-1 & FP-2).   With the Hand-Off-Auto switch (HS-1) in the Auto position, the centrifugal pumps (FP-1 & FP-2 - alternating) will be controlled by the high level (LSH-1) and the low level (LSL-1) float switches in the influent tank (T-1). After the high level (LSH-1) initiates the start-up of FP-1, the flow switch (FS-1) shall monitor for flow. If flow is not detected after 15 seconds, the flow switch (FS-1) shall initiate the starting of the second pump (FP-2). An alarm shall indicate that FP-1 did not start and an alarm message shall be sent to the remote dialer. After the low level (LSL-1) initiated the shutdown of the feed pump (FP-1 or FP-2) the flow switch (FS-1) shall terminate the monitoring for flow.

In the event that a high high level (LSHH-1) is encountered in the influent tank (T-1), the switch shall: (1) prevent the operation of the collection trench pump (CTP-1), (2) close the solenoid valve on the air supply line to the Extraction Wells (SOL-1) and to the collection trench pump (SOL-2), (3) send a signal to initiate shutdown of the chemical precipitation system, and (4) initiate an alarm status to the remote dialer. The feed pumps (FP-1 & FP-2) shall be manually reset.

4.5.   CHEMICAL PRECIPITATION SYSTEM (CP-1).   The chemical precipitation unit shall be operated to remove metals and pre-treat for non-hazardous ions such as iron, which may interfere with the downstream processes. The unit shall have pH monitors to control the chemical addition for pH adjustment. The chemical feed pumps will be energized and controlled by the chemical precipitation units integral control unit.   The level switches, LSL-1 and LSH-1 located in the influent tank (T-1), shall initiate the chemical precipitation system start-up and shutdown during normal operation.
The high high level (LSHH-1) in the influent tank (T-1) shall initiate the shutdown of the chemical precipitation system.

4.5.1.   CHEMICAL FEED SYSTEMS. The manufacturer shall recommend the chemical feed systems.   The pH monitors will determine the necessity for acid/caustic addition. The chemical and polymer feed pumps shall be controlled by the integral control panel of the chemical precipitation unit, which in turn is controlled by the level switches (LSL-1, LSH-1, and LSH-1) located in the influent tank (T-1).

4.5.2.   INCLINED PLATE CLARIFIER   (IPC-1).   The chemical precipitation unit manufacturer shall recommend an inclined plate clarifier including size and controls. The included plate clarifier shall remove and concentrate the settleable solids from the wastewater stream. The integral sludge chamber thickener will run continuously or as recommended by the supplier, to mechanically release entrained air from the sludge.

4.5.2.1.   Sludge Transfer Pumps (SP-1 & SP-2). The air diaphragm sludge pumps (SP-1 & SP-2 - alternating) shall operate as recommended by the manufacturer and shall be controlled by the chemical precipitation unit's

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integral control panel. After the chemical precipitation unit's control panel initiates the start-up of sludge pump (SP-1) by energizing the air supply line solenoid valve (SOL-2), the flow switch (FS-4) shall start monitoring for flow. If flow is not detected after 15 seconds, the flow switch (FS-4) shall initiate the starting of the second sludge pump (SP-2) by energizing the air supply line solenoid valve (SOL-3). An alarm shall indicate that SP-1 did not function and an alarm message shall be sent to the remote dialer.

4.6. **POLISHING PRESSURE FILTERS (PF-1).** The pressure sand filters will remove the suspended solids before the groundwater flows to the tray aerator. The sand filters will automatically backwash. Both a pressure differential and a timer shall be provided for the backwashing operation. Treated Effluent or raw water will be used for backwashing the filters.

4.6.1. **POLISHING FILTER PUMPS (PFP-1 & PFP-2).** With the Hand-Off-Auto switch (HS-8) in the Auto position, the air stripper system blower (B-1) will be controlled by the high level (LSH-2) and the low level (LSL-2) float switches in the tray aerator sump tank (T-2). After the high level (LSH-2) initiates the start-up of B-1, the flow switch (FS-3) shall monitor for airflow. If airflow is detected in flow switch (FS-3) the feed pumps (PFP-1 and PFP-2 - alternating) shall be energized. If airflow is not detected after 10 seconds, the flow switch (FS-3) shall: (1) prevent the start-up of pumps (PFP-1 and PFP-2) and (2) initiate an alarm status to the remote dialer.

The low level (LSL-2) float switch located in the aerator sump tank (T-2) shall: (1) de-energize the pumps (PFP-1 & PFP-2), (2) initiate a 5 minute timed delay shutdown of the blower (B-1), and (3) the flow switches (FS-2) and (FS-3) shall terminate the monitoring for flow.

After the flow switch (FS-3) initiates the start-up of PFP-1, based on the level in the aerator sump tank (T-2), the flow switch (FS-2) shall monitor for flow. If flow is not detected after 15 seconds, the flow switch (FS-2) shall initiate the starting of the second pump (PFP-2) An alarm shall indicate that PFP-1 did not start and an alarm message shall be sent to the remote dialer. After the low level (LSL-2) initiated the shutdown of the feed pump (PFP-1 or PFP-2) the flow switch (FS-2) shall terminate the monitoring for flow. The feed pumps (PFP-1 & PFP-2) shall be manually reset.

In the event that a high high level (LSHH-2) is encountered in tank (T-2), the switch shall: (1) prevent the operation of the feed pump (FP-1 or FP-2), (2) shutdown the blower (B-1) on the tray aerator after a timed delay of 5 minutes, (3) initiate an alarm status to the remote dialer.

4.7. **AIR STRIPPER SYSTEM (AS-1).**

4.7.1. **BLOWER (B-1).** With the Hand-Off-Auto switch (HS-8) in the Auto position, the blower shall be controlled by th high level (LSH-2) and the low level (LSL-2) float switches in the aerator sump tank (T-2). If the blower has been energized and the flow switch (FS-3) does indicate airflow, the flow switch (FS-3) shall: (1) prevent the operation of the feed pumps (PFP-1 & PFP-2) and (2) initiate an alarm status to the remote dialer.

4.7.2.   TRAY AERATOR SUMP DISCHARGE PUMPS (DP-1 & DP-2). With the
Hand-Off-Auto switch (HS-3) in the Auto position, the pumps (DP-1 & DP-2 -
alternating) shall be controlled by the high level (LSH-3) and the low level
(LSL-3) float switches in the tray aerator sump tank (T-2). After the high level
(LSH-3) initiates the start-up of DP-1, the flow switch (FS-5) shall monitor for
flow. If flow is not detected after 15 seconds, the flow switch (FS-5) shall
initiate the starting of the second pump (DP-2). An alarm shall indicate that
DP-1 did not start and an alarm message shall be sent to the remote dialer. After
the low level (LSL-3) initiated the shutdown of the discharge pump (DP-1 and DP-
2) the flow switch (FS-5) shall terminate the monitoring for flow.

In the event that a high high level is encountered in the air stripper sump tank
(T-2), the switch (LSHH-3) shall: (1) de-energize the pressure filter pumps (PFP-
1 and PFP-2), (2) shutdown the blower (B-1) on the tray aerator after a timed
delay of 5 minutes, and (3) initiate an alarm status to the remote dialer. The
feed pumps (DP-1 & DP-2) shall be manually reset.

4.8.   LIQUID PHASE GAC ADSORPTION FILTERS (LGAC-1).   Space shall be
provided for a second unit, currently not included under this contract. A sample
port shall provide downstream of the unit. Pressure indicators, located upstream
and downstream of the unit, shall determine the pressure loss through the unit.
A recycle line shall be located downstream of the liquid GAC unit to recycle the
treated groundwater back through the system.

4.9.   FINAL PH ADJUSTMENT/ EFFLUENT TANK (T-4). Preceding the effluent
tank, an in-line pH monitor and in-line static mixer shall provide for final pH
adjustment.   The necessary chemical storage tank and feed system shall be
provided as recommended by the chemical precipitation unit supplier. The treated
effluent will be used for housekeeping, chemical dilution and mixing, and
potentially for backwashing the pressure filters. The Contractor shall determine
whether or not the discharge can be a gravity flow system controlled by a
solenoid valve or a pressurized system controlled by discharge pumps (DP-3 & DP-4
- alternating).   If the discharge is a gravity system, the high level (LSH-6)
located in the effluent tank (T-4) shall energize the valve and allow the treated
effluent to drain out of the tank. The low level (LSL-6) located in the effluent
tank (T-4) shall close the valve.

In the event that a high high level is encountered in the effluent tank (T-4),
the switch (LSHH-6) shall: (1) prevent the operation of the tray aerator sump
discharge pumps (DP-1 & DP-2) and (2) initiate an alarm status to a remote
dialer.

4.9.1.   EFFLUENT DISCHARGE PUMPS (IF REQUIRED) (DP-3 & DP-4). With
the Hand-Off-Auto switch (HS-6) in the Auto position, the pumps (DP-3 & DP-4 -
alternating) will be controlled by the high level (LSH-6) and the low level (LSL-
6) float switches in the effluent tank (T-4).   After the high level (LSH-6)
initiates the start-up of DP-3, the flow switch (FS-6) shall monitor for flow.
If flow is not detected after 15 seconds, the flow switch (FS-6) shall initiate
the starting of the second pump (DP-4). An alarm shall indicate that DP-3 did
not start and an alarm message shall be sent to the remote dialer. After the low
level (LSL-6) initiated the shutdown of the discharge pump (DP-3 and DP-4) the

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flow switch (FS-6) shall terminate the monitoring for flow. The LSL-6 shall also prevent the operation of the effluent pump (EP-1). The feed pumps (DP-3 & DP-4) shall be manually reset.

4.9.2. **EFFLUENT PUMP (EP-1).** The effluent pump will be controlled by the hydropneumatic tank. The tank has an operating range of 30 to 50 psi. When the pressure switch reads 50 psi the effluent pump (EP-1) will stop and when the pressure switch reads 30 psi the effluent pump (EP-1) will start. The low level (LSL-6) switch located in the effluent tank (T-4) shall protect the effluent pump from pumping dry. The effluent pump shall automatically reset.

4.9.3. **HYDROPNEUMATIC TANK (HP-1).** The hydropneumatic tank will provide a non-potable water source for housekeeping, chemical dilution and mixing purposes. The tank will operate between 30 psi and 50 psi.

4.9.4. **BACKWASH PUMPS (IF REQUIRED) (BW-1 & BW-2).** The Contractor shall determine the controls for the backwash pumps based on recommendations from the pressure filter supplier. The supplier shall provide the appropriate sized the pumps.

4.10. SLUDGE HANDLING SYSTEM

4.10.1. **PLATE FILTER PRESS (PFP-1).** The plate filter press shall have an integral control panel that shall have controls recommended by the supplier. The controls shall include, but not limited too (1) over-pressurizing, (2) prevent the press from opening too far, (3) prevent the accidental closing when the cake is being dumped, etc. The plate press integral controller shall send a signal to the remote dialer when the press is full or under any of the recommended alarm conditions.

4.10.2. **AIR DIAPHRAGM PUMPS (ADP-1 & ADP-2).** The air diaphragm type sludge pumps (ADP-1 & ADP-2 - alternating) shall operate as recommended by the manufacturer or as described herein. With the Hand-Off-Auto switch (HS-4) in the Auto position, the pumps (ADP-1 & ADP-2) shall be controlled by the high level (LSH-4) and the low level (LSL-4) float switches in the sludge holding tank (T-3). The high level (LSH-4) shall start the sludge pump (ADP-1) by energizing the air supply line solenoid valve (SOL-5) to open and shall initiate the flow switch (FS-7) to start monitoring for flow. If flow is not detected after 15 seconds, the flow switch (FS-7) shall initiate the starting of the second sludge pump (ADP-2) by energizing the air supply line solenoid valve (SOL-6). An alarm shall indicate that ADP-1 did not function and an alarm message shall be sent to the remote dialer. After the low level (LSL-4) initiated the shutdown of the sludge pump (ADP-1 and ADP-2) be de-energizing the air supply line solenoid valves (SOL-5 & SOL-6), the flow switch (FS-7) shall terminate the monitoring for flow. In the automatic mode, the pumps shall operate off a process controller from the filter press. When the press is full, the controller shall close the air solenoid valve, stopping the pumps and initiating an alarm status to the remote dialer.

In the event that a high high level is encountered in the sludge holding tank (T-3), the switch (LSHH-4) shall: (1) prevent the operation of the sludge pumps (SP-

1 & SP-2) controlled by the chemical precipitation unit's integral control panel and (2) initiate an alarm status to the remote dialer.

4.11. BUILDING SUMP PUMPS (SP-3 & SP-4). With the Hand-Off-Auto switch (HS-7) in the Auto position, the submersible pumps (SP-3 & SP-4 - alternating) shall be controlled by the high level (LSH-7) and the low level (LSL-7) float switches in the building sump. After the high level (LSH-7) initiates the start-up of SP-3, the flow switch (FS-8) shall monitor for flow. If flow is not detected after 15 seconds, the flow switch (FS-8) shall initiate the starting of the second pump (SP-4). An alarm shall indicate that SP-3 did not start and an alarm message shall be sent to the remote dialer. After the low level (LSL-7) initiated the shutdown of the sump pump (SP-3 and SP-4) the flow switch (FS-8) shall terminate the monitoring for flow.

In the event that a high high level is encountered in the building sump, the switch (LSHH-7) shall: (1) prevent the operation of the feed pumps (FP-1 & FP-2) and (2) initiate an alarm status to a remote dialer.

5. START-UP WATER GENERATION.

5.1. **Storage of Start-Up Water.** The first treated water shall be stored in on-site Baker tanks for analysis. The water shall be analyzed to ensure that it will meet the effluent requirements.

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APPENDIX A

ENVIRONMENTAL CALCULATIONS

PROJECT: Boarhead Farms, PA	SHEET N	1	OF
SUBJECT: Sizing the Piping from the Wells to Plant Sizing	BY JMM DATE: 24 Apr 96		
	CHKD. BY DATE: 5·21·96		

REFERENCES:

1. Hydraulics Handbook by Colt.
2. Pneumatic Air Driven Pumps

1. Size the piping

Headloss using Hazen-Williams Equation for Pressure Pipe where Q= flowrate (gpm);
D= diameter (in); C= Roughness Coefficient (new C=130); L= length (ft)
S= slope (ft/ft of hydraulic gradient); Headloss = slope X Length (ft)

(A) Friction Headlosses

Description of Run	Flowrate gpm	length ft	diameter inches	Hdloss ft	Remarks
EW11 to Pt 1	1	350	1.0	0.4	Longest Run
EW10 to Pt 1	3	25	1.0	0.3	
Pt 1 to Pt 2	4	200	1.0	3.6	Longest Run
EW9 to Pt 2	3	100	1.0	0.7	
Pt 2 to Pt 3	7	150	1.0	6.5	Longest Run
EW8 to Pt 3	6	75	1.0	2.3	
Pt 3 to Pt 4	12	150	1.5	9.3	Longest Run
EW13 to Pt 5	2	200	1.0	0.9	
EW 15 to Pt 5	5	75	1.0	1.9	
Pt 5 to Pt 6	7	225	1.5	5.0	
EW6 to Pt 6	6	250	1.0	8.8	
Pt 6 to Pt 4	13	150	1.5	10.4	
EW 17 to Pt 4	5	100	1.0	2.5	
Pt 4 to Plant	30	50	2.0	9.7	Longest Run

Longest Run Piping Friction losses =   29.6 ft

(B) Minor Losses Longest Run   Cumulative Flowrate   15 gpm

Type of loss	Dia. in	Length ft	k	v (fps)	k(v*v/2g)	Total Hdloss
3 x Tees (Branch)	1	0	0.35	6.13	0.20	0.61
2 x Tee (Branch)	1.5	0	0.22	2.72	0.03	0.05
2 x Tee (Branch)	2	0	0.2	1.53	0.01	0.01
2 x Gate Valves	2	0	0.5	1.53	0.02	0.04
3 x elbow 90	1	0	1	6.13	0.58	1.75

Total Minor Losses =   2.46   ft

(C) Static Headlosses

Finished Floor Elevation of Building (Estimated - Worst Case)	5775	m.s.l.
Groundwater Surface Elevation (Lowest - Worst Case) =	5725	m.s.l.
Static Differences due to water levels =	50	ft
Influent Tank Maximum Height =	-13	ft
Estimated Pump Submergence =	25	ft

(C) Total Headlosses from Wells to Pumphouse

Friction losses + minor losses + static differences + influent tank elevation + pump submergence =

Total Headloss =   120 ft

Note : The pump submergence may vary with the anticipated drawdown. Assume a maximum pump
pump depth placement of 75 ft. Therefore the operating point is approx. the flowrate at 120ft TDH.
The assumed maximum TDH for the wells is 200 ft.

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REFERENCES:

1. Hydraulics Handbook by Colt.
2. Assume minor losses 15 % of friction losses

1. Determine the Total Headlosses from Trench to Influent Tank

Headloss using Hazen-Williams Equation for Pressure Pipe where Q= flowrate (gpm);
D= diameter (in); C= Roughness Coefficient (new C=130); L= length (ft)
S= slope (ft/ft of hydraulic gradient); Headloss = slope X Length (ft)

(A) Friction Headlosses

Description of Run	Flowrate gpm	length ft	diameter inches	Hdloss ft	Remarks
Trench to T-1	20	300	3.0	12.9	

Minor Losses assume 15 % of Friction losses   1.9 ft

(B) Static Headlosses

Finished Floor Elevation of Building (Estimated - Worst Case   5775   m.s.l.
Trench Sump Elevation (Lowest - Worst Case) =   5735   m.s.l.

Static Differences due to water levels =   40   ft

Influent Tank Maximum Height =   13   ft

(C)   Total Headlosses from Wells to Pumphouse

Friction losses + minor losses + static differences + influent tank elevation

Total Headloss =   68 ft

OMAHA DISTRICT | CALCULATION SHEET | CORPS OF ENGINEERS

PROJECT	Boarhead Farms, PA	SHEET N	1	OF

SUBJECT: Pressure Filter & Backwash Requirements	BY JMM	DATE: 20 May 96
	CHKD. BY TA	DATE: 5·21·96

Per Discussions with Manufacturers and Recommendations for Design

(A) Process Flowrate =   75 gpm

(B) Hydraulic Loading Rate =   4 to 6 gpm/sqft

therefore the Total Surface Area Required =   12.5   to   18.8 sqft

Minimum of 2 vessel filtration system =   6.3   to   9.4 sqft per vessel

Three vessel filtration system =   4.2   to   6.3 sqft per vessel

(C) Recommended Backwashing Rate = 10 to 15 gpm / sqft per vessel
(D) Recommended Backwash Time Period = 8 to 15 minutes per vessel

Backwash water required

Example: 6.3 sqft * 10 gpm/sqft * 8 minutes =   500   gallons

<u>2 vessels</u>

10 gpm/sqft at 8 minutes = 504 to 752 gallons
15 gpm/sqft at 15 minutes = 1418 to 2115 gallons

<u>3 vessels</u>

10 gpm/sqft at 8 minutes = 336 to 504 gallons
15 gpm/sqft at 15 minutes = 945 to 1418 gallons <<==

Use a three vessel filtration system if possible !!!

(E) Add 5 minutes of settling and draining flowrate

Backwash required = 1418 + 5 min*10 gpm/sqft*6.3 sqft

Total =   1733   gallons

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Worst Case Scenario - The Filters could be backwashing the same time the filter press is processing the full sludge storage volume.

Flow into sump: (1) Sludge Holding Tank decant =   Negligible
                 (2) Intermittent Backwash from filters / cycle = 1733 gallons
                 (3) Filtrate from Plate Filter Press =   400 gallons

<u>Worst Case Scenario Total Volume required for sump & trench =   2133 gallons</u>

Conversion Factor 1 cft = 7.48 gallons   **Use 2100 gallons**

Cubic feet required =   281 cft

(A) Storage Capacity in trench drain

Depth of trench =   12 inches
Width of Trench Drain =   12 inches
Length of Trench Drain =   45 feet

Storage Capacity in Trench Drain =   45.0   cft

(B) Sump Sizing minus trench storage   236 cft

depth ft	width ft	length ft	volume cuft	volume gallons	
7	6	6	252	1885	
8	5	6	240	1795	
10	5	5	250	1870	<<==
12	4	5	240	1795	

Use a 5 ft W X 5 ft L X 10 ft D Sump

With a 3 ft by $\frac{Y}{5}$ ft grated opening

(B) Building Containment

Worst Case Scenario - Influent tank ruptures.

Influent Tank (T-1) =   7,000 gallons =   936 cft

Process Area Size
     (40ft x 60ft) =   2,400 sqft

Curb height =   6 inches

Building Containment =   1,200 cft which is greater than the
                                         required volume required.

<u>Building Curb Height =   6 inches</u>

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(A) Treatment Plant Flowrate

Sustained 8 hour Flowrate from 8 Extraction Wells =   30 gpm
Peak Flowrate from Collection Trench Sump =   20 gpm
Recycle Stream =   20 gpm intermittently

(B) Plant Operation

The plant will operate at a fixed flowrate of 75 gpm, batch mode.

(C) Equalization Tank Sizing

Storage Period =   1 hrs
Total Gallons =   7000 gallons   (1 hr and 33 minutes storage capacity at 75 gpm)

Case 1 - Flow into plant equals 75 gpm and the level control in the equalization tank reaches the 3,500 gallon mark and starts the feed pumps and chemcial feed system
The plant will operate at 75 gpm for approx. 45 minutes and will stop to refill. *ASSUMING INFLUENT FLOWRATE IS TERMINATED.*

Case 2 - If the flowrate is 75 gpm into the plant, the tank will fill and the plant will run continuously. When the filters backwash (estimated once a day) the tank will have additional storage to store the backwash. The collection trench may be shutdown periodically if the peak flowrate is sustained longer than estimated. *, PUMPED TO THE EQ TANK AT A CONSTANT 20 gpm.*

(a) The start up sequence will be to energize the feed pumps and the chemical precipitation process, which includes chemical feed pumps, mixers etc.
(b) All process pumps will be controlled with level controls in the appropriate storage sumps.
The pumps will be started and stopped by these level controls.
(c) The mixers in the flocculant tank will run continuously, or run based on the manufacturer's recommendations.
(d) A high high level alarm in the equalization tank will stop the collection trench sump pump.
The collection trench has one day of storage capacity. A remote alarm will be initiated.
The collection trench sump pump will be reenergized when the plant starts its operation again.

Total size of the equalization tank =   7,000 gallons

Diameter ft	Height ft
10	11.9
12	8.3

Notes: (1) Package chemical precipitation units are manufacturered by several vendors.
    (2) The starting and stopping of the operation should not affect the chemical precipitation unit.
    (3) Under this contract the maximum flowrate into the plant is 50 gpm.
    (4) The recycle stream is intermittently 20 gpm. *→ PUMPED FLOWRATE FROM BW STORAGE VAULT.*
        a) Sludge tank decant - negligible
        b) Filtrate from press 0 to 20 gpm during operation only - intermittent flow
        c) Pressure filter backwash ranges from 30 gpm/ft^2 for 8 min to 140 gpm for 15 min
           (The contractor shall size the backwash pumps based on the pressure filters chosen)

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References: Hydraulics Handbook by Colt for "K" values

Headlosses for straight sections of piping were calculated using a modified form of Hazen-Williams Equation.

Desired Flowrate (Q) = 75 gpm   Diameter (D) = variable inch
Roughness Coef. (C) = 130   Length (L) = variable feet

(A) Feed Pumps to Chemical Precip. Unit (FP-1 & FP-2)

Type of loss	Dia. in	Length ft	k	v (fps)	k(v*v/2g)	Piping Hdloss	Total Hdloss
Pipe	2	25				3.2	3.2
Check Valve	2	0	2.5	7.66	2.28		2.3
3 X Elbow 90	2	0	0.4	7.66	0.36		1.1
				Total Friction Losses =		6.6	ft
				Plus 10% for piping variations =		7.3	ft

Static Elev differences (Bldg Clear Height) = 15 ft

Total Headloss = Friction + Static Losses

TOTAL HEADLOSS = 22 ft

(B) Polishing Filter Pumps to Tray Aerator (PFP-1 & PFP-2)

Type of loss	Dia. in	Length ft	k	v (fps)	k(v*v/2g)	Piping Hdloss	Total Hdloss
Pipe	2	75				9.7	9.7
Check Valve	2	0	2.5	7.66	2.28		2.3
3 X Tee (2x2)	2	0	1.9	7.66	1.73		5.2
10 X Elbow 90	2	0	0.4	7.66	0.36		3.6
				Total Friction Losses =		20.8	ft
				Plus 10% for piping variations =		22.9	ft

Converstion Factor   1 psi = 2.31 ft

Pressure Losses through Filters = 15 psi = 35 ft

Static Elev differences (Bldg Clear Height) = 15 ft

Total Headloss = Friction Losses+ Pressure Losses + Static Losses

TOTAL HEADLOSS = 73 ft

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References: Hydraulics Handbook by Colt for "K" values

Headlosses for straight sections of piping were calculated using a modified form of Hazen-Williams Equation.

Desired Flowrate (Q) = 75 gpm   Diameter (D) = variable inch
Roughness Coef. (C) = 130   Length (L) = variable feet

(C) Tray Aerator / Discharge Pumps (DP-1 & DP-2)

Type of loss (thru Process)	Dia. in	Length ft	k	v (fps)	k(v*v/2g)	Piping Hdloss	Total Hdloss
Pipe	2	75				9.7	9.7
Check Valve	2	0	2.5	7.66	2.28		2.3
3 X Tee (2x2)	2	0	1.9	7.66	1.73		5.2
10 X Elbow 90	2	0	0.4	7.66	0.36		3.6

Total Friction Losses = 20.8 ft

(1) Plus 10% for piping variations = 22.9 ft

(2) Pressures Losses through Liquid GAC = 10 psi = 23 ft
(3) Static Difference = 10 ft

Total Headloss = Friction losses (thru Process)+ Pressure losses (Liquid GAC) + Static Differences

Total Headloss   56 ft

(D) Discharge Pumps (DP-3 & DP-4)

NOTES: (a) The building location will be identified after the soil borings and sampling results have been reviewed.
(b) The discharge location will be determined during construction with the approval of the Contracting Officer's Representative.
(c) The discharge piping will be sized by the Contractor. The Discharge will be either gravity or pressure.

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References: Hydraulics Handbook by Colt for "K" values

Headlosses for straight sections of piping were calculated using a modified form of Hazen-Williams Equation.

Desired Flowrate (Q) =   20 gpm   Diameter (D) =   variable inch
Roughness Coef. (C) =   130   Length (L) =   variable feet

(F) Sump Pump (SP-1)

Type of loss	Dia. in	Length ft	k	v (fps)	k(v*v/2g)	Piping Hdloss	Total Hdloss
Pipe	1	25				8.2	8.2
Check Valve	1	0	2.5	8.17	2.59		2.6
3 X Elbow 90	1	0	0.4	8.17	0.41		1.2
				Total Friciton Losses =		12.0	ft
				Plus 10% for piping variations =		13.2	ft

Static Elev differences =   19 ft 22
(Bldg Clear Height+Sump Elevation)

Total Headloss = Friction + Static Losses

35

TOTAL HEADLOSS =   32 ft

(G) Effluent Pump (EP-1)

Desired Flowrate (Q) =   20 gpm   Diameter (D) =   variable inch
Roughness Coef. (C) =   130   Length (L) =   variable feet

Type of loss	Dia. in	Length ft	k	v (fps)	k(v*v/2g)	Piping Hdloss	Total Hdloss
Pipe	1	15				4.9	4.9
Check Valve	1	0	2.5	8.17	2.59		2.6
3 X Elbow 90	1	0	0.4	8.17	0.41		1.2
				Total Friciton Losses =		8.7	ft
				Plus 10% for piping variations =		9.6	ft

Static Elev differences (T-4 to Hydropnuematic Tank)=   0 ft

Conversion Factor
1 psi = 2.31 ft

Hydropneumatic Tank Pressure =   50 psi =   116 ft

Total Headloss = Friction Losses+ Pressurized Tank + Static Losses

TOTAL HEADLOSS =   125 ft

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Parameters for liquid GAC

1. Plant Flowrate = 75 gpm
2. Empty Bed Contact Time = 5 to 10 minutes (liquid polishing only)
3. Area = pi d^2 / 4 (ft^2)
4. GAC Bulk Density for bituminous material 28 pcf

(A) Conversions

7.48 gallons = 1 cubic foot

(B) Empty Bed Contact Time (EBCT)

EBCT = L / (Q/A) which equals V / Q

therefore V ft^3 = EBCT min * Q gpm / 7.48 g/ft^3

where: L = bed length (ft); Q = flowrate (gpm); A = area (ft^2);
V = volume carbon (ft^3)

lbs carbon = v ft^3 * bulk density lbs/ft^3

EBCT min	Volume ft^3	carbon lbs
5	50.1	1,404
10	100.3	2,807

(C) Hydraulic Loading gpm/ft^2
hydraulic loading = flowrate / ft^2 surface area
recommended hydraulic loading for liquid GAC
2 to 10 gpm/ft^2

Diameter ft	Area ft^2	Hyd Load gpm/ft^2
3	7.1	10.6
4	12.6	6.0
5	19.6	3.8

==>>

(D) Bed Depth ft

lbs Carbon / bulk density (lbs/ft^3) / area (ft^2) = bed depth ft

Carbon Vessels will be replaced when exhausted.

EBCT min	Carbon lbs	Diameter ft	Area ft^2	bed depth ft	total bed dpth ft
5	1404	3	7.1	7	8.5
5	1404	4	12.6	4	4.8	<<==
5	1404	5	19.6	3	3.1

EBCT min	Carbon lbs	Diameter ft	Area ft^2	bed depth ft	total bed dpth ft
10	2807	3	7.1	14	17.0
10	2807	4	12.6	8	9.6	<<==
10	2807	5	19.6	5	6.1

NOTES: (a) A 2000 lb unit is the largest GAC vessel that can be removed/replaced when the carbon is exhausted.
(b) The EBCT was recommended between 5 to 10 minutes.

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Influent flowrate under this project is 50gpm plus recycle stream.

Sludge 2-3% by volume of plant flowrate per conversation with chemical precip. manufacturers

75 gpm * .02 = 1.50
75 gpm * .03 = 2.25 gpm   Use 2gpm b/c of variable influent rate

(A) Q INTO SLUDGE HOLDING TANK = $2.00 \, gpm * \dfrac{60min}{hr} * \dfrac{24 \, hrs}{d}$

WORST CASE:
Operation is 24 hrs/d batch mode ∴ 28.80 g/d sludge produced

(B) TSS of sludge into filter press = 0.2% to 0.5%   use .3% or 3000 ppm

Q into Filter Press starts at 20gpm

$SOLIDS = 2.00 \, gpm * \dfrac{8.34 \, lb}{g} * \dfrac{60min}{hr} * \dfrac{24hr}{d} * \dfrac{3000 \, lb}{10^6 \, lb}$

= 72 lb   say 70 lbs/day

(C) Assume .75 lbs/ft³ & 50% cake dryness

cake volume = $\dfrac{70 \, lbs}{d} * \dfrac{ft^3}{75 \, lbs} * \dfrac{1}{.5} = 1.87 \, ft^3/d$

* Model 630 J.D. Anderson Plate Filter Press has 6.5 Ft³ cake capacity

$\dfrac{6.5 ft^3}{1.87} = \underline{3.5 \, days}$

Dump filter Press twice a week for WORST CASE with a 6.5 cu ft press

Sludge produced at ≈ 2 gpm → Sludge holding tank

Sludge pumped from tank to press at 20 gpm

Ⓐ 2880 g/d of Sludge produced

Assume 20 gpm Air Diaphragm Pump to transfer
Sludge from holding tank to filter Press

Ⓑ Use 1,000g Sludge holding tank, useable volume
800g

Fills to 800gal in $800g * \frac{Min}{2.0g} * \frac{hr}{60min} = 6 \frac{2}{3}$ hours

Empties @ 20gpm $800g * \frac{min}{20g} = 40$ mins

Ⓒ Sludge dewatering operation
one to three times a day depending upon how often
the plant operates.

Calculate the stability of $CaCO_3$

Fig. 7.9 page 7.16 The Nalco Water Handbook

assume Alkalinity = 25 mg/l
  Ca Hardness = 259.5 mg/l as $CaCO_3$
  water temp = 55°F
Assume pH water quality = 8
pH value at saturation, pH_s = 8.2

use Ryznar index for flowing systems where the velocity is greater than 2ft/s (modified Langelier index)

$$Stability\ index\ (SI) = 2pH_s - pH$$

water solution is corrosive when the SI >6.0
water solution is scale forming when SI <6.0

Solve for max. pH to keep $CaCO_3$ in solution and prevent scaling using SI

$$6 = 2(8.2) - pH$$

$$pH = 10.4$$

Langelier index - low velocity of flow , LI

    if LI is positive. The water is likely to form scale
    if LI is negative The water will dissolve $CaCO_3$

$$LI = pH - pH_s$$

∴ max pH to keep $CaCO_3$ in solution
is = 8.2 ie) $LI = 8.0 - 8.2 = (-0.2$

Note. as the water temperature increases, the pH_s decreases

On the other hand, if the water sample is undersaturated with respect to $CaCO_3$—that is, if it is an aggressive, corrosive water—then some of the fine marble added to the sample dissolves, increasing the hardness, alkalinity, and pH. This water is said to have a *negative saturation index.*

Working with the $CaCO_3$ equilibrium values, incorporating the dissociation factors for carbonic acid, bicarbonate, and carbonate, and based on the theoretical solubility of $CaCO_3$ at different temperatures, as affected by water salinity, Langelier developed a method for predicting the saturation pH (called pH_s) of any

Ca Hardness, mg/l as $CaCO_3$ pH Value at Saturation (pH_s)
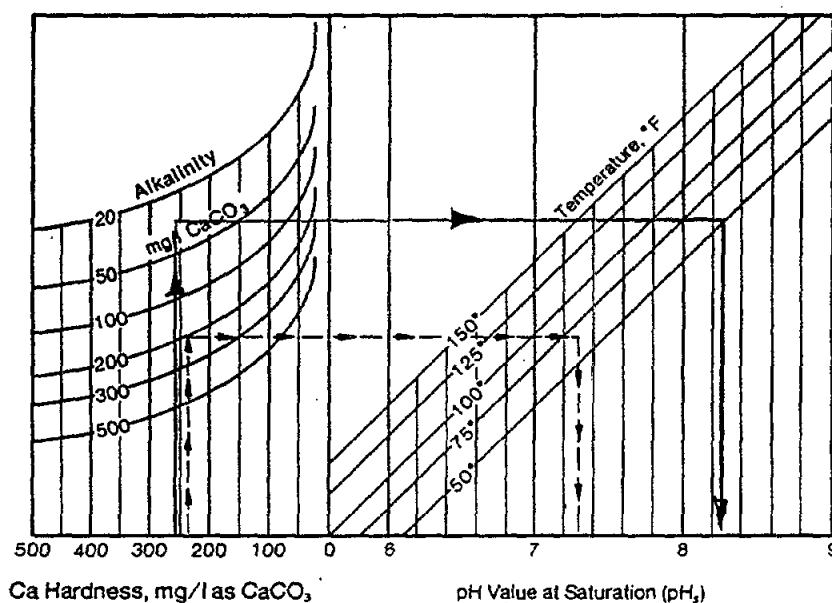
EXAMPLE:
Raw Water Calcium	= 240 mg/l
Alkalinity	= 190 mg/l
pH	= 6.8
Temperature	= 70°F
From Chart: pH_s	= 7.3
Langelier Index	= 6.8 − 7.3 = −0.5

FIG. 4.9 Determination of pH_s and Langelier index from hardness, alkalinity, and temperature.

water. If the actual pH of the water is below the calculated level (pH_s), the water has a negative Langelier index and will dissolve $CaCO_3$. This is generally also interpreted to indicate that the water may be corrosive to steel if oxygen is present. If the measured pH exceeds pH_s, the Langelier index is positive, and being supersaturated with $CaCO_3$, the water is likely to form scale. The greater the deviation of actual pH from pH_s, the more pronounced is the instability. The

saturation pH, and the Langelier ind by reference to Figure 4.9.

Langelier i

Based on studies of reported con of municipal systems, Ryznar modif dict the likelihood of scale forming c using his *Ryznar index* or *stability i*

Stability inde

In using this index, a water solu stability index exceeds approximatel is less than 6.0

The Langelier index is most usef velocity of flow), such as a lime soft empirical and applies only to flowin wall is quite different from that of 20.6) If corrosion is occurring, oxide ditions at the cathode and anode fr solids are present, the velocity of flo· formation from sedimentation that wetting the pipe wall. As a general n systems and the Ryznar index in f than about 2 ft/s (0.6 m/s), or suffic

The Langelier index has been m· where the high salinity affects ionic s index is:

$$SDI = pH$$

where pH is used as measured,

$$pCa = \log I/[Ca]$$

$$pAlk = \log I/[Alk]$$

$$K = \text{constant based on}$$

Ionic strength of the solution is c from temperature using Figure 4.1(Figure 4.11.

Such data developed for oil-field cations such as treatment of open discharge. Similar indexes have be minerals depositing in distribution these indexes are those for calcium are of much more limited value to t index, chiefly because of the variet solubility values for each of the cor

The effect of ionic strength is · solubility in a concentrating recirc

Cations	mg/l	Eq wt	Anions	mg/l	Eq wt
Ca^{+2}	101.8	20	SO_4^{-2}	400	$\frac{·87}{2}$ = 43.5
Fe^{+2}	37	27.9	Cl^-	18	35.4
Mg^{+2}	44	12.2			
Mn^{+2}	4	27.5	Alk = 25 mg/l @ $CaCO_3$		

Hardness   mg/l as $CaCO_3$ = M^{+2} mg/l * $\frac{50}{eq\ wt\ of\ M^{+2}}$

(eq 18-1)   Env Chem Textbook

		Hardness as mg/l $CaCO_3$
Ca^{+2}	101.8(50)/20	= 254.5
Mg^{+2}	44(50)/12.2	= 180.3
Fe^{+2}	37(50)/27.9	= 66.3
Mn^{+2}	4(50)/27.5	= 7.3

508.4 mg/l as $CaCO_3$

Total hardness > alkalinity

508.4 > 25

Carbonate hardness = alkalinity

Non Carbonate hardness (NCH) = Total hardness -

carbonate hardness

483.4 mg/l NCH

air diaphragm pump

Sludge holding tank to Plate Filter Press

Assume:
- max flow to Press is 50 gpm
- OPERATING Flow = 20 gpm
- max discharge head into press is 100 psi
  (to form a compact filter cake) - manufacturer's info.

- sludge will include BTEX & chlorinated
  solvents requiring special materials for
  diaphragm and wetted housing

- use air operated double diaphragm sludge
pump.

Select pump
- teflon diaphragm material
- max flow 40 gpm (teflon diaphragm reduces
    flow rates) - OPERATING = 20 gpm
- total Dynamic head - 95 psig
- max. operating air supply required - 110 psig
- max air consumption - 60 scfm

- Actual pump selection will depend upon selected
Plate filter press.

WILDEN® MODEL M4®

Height .... 18"
Width .... 14¼"
Depth .... 11¼"
Weight ..... ALUMINUM 35 lbs.
        IRON OR STAINLESS 52 lbs.
Air Inlet .... ¾" N.P.T.
Inlet .... 1½" Female N.P.T.
Outlet ..... 1¼" Male N.P.T.
Suction Lift .... 22' Dry
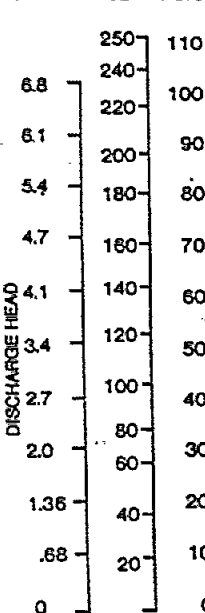   27' Wet
Max. Size Solids .. ³⁄₁₆" Dia.

Example: To pump 22.5 gpm against a discharge pressure head of 45 psig, requires 60 psig and 20 sclm air consumption (See dot on chart.)

Note: For M4 pumps fitted with Teflon diaphragms reduce water discharge figures by 20%. Suction lift for M4 pumps with Teflon diaphragms: 12 ft. dry, 25 ft. wet.

Caution: Do not exceed 125 psig air supply pressure.

SUCTION LIFT DATA

SUCTION LIFT FEET	AIR SUPPLY PSI	DISCHARGE PRESSURE PSI	GPM LOSS
0	100	0	0
−5	100	0	−4
−10	100	0	−8
−15	100	0	−12
−20	100	0	−16
−25	100	0	−20

Special Note: When calculating flow rate, loss in G.P.M. from suction lift must be subtracted from performance shown on curves which are based on flooded suction (zero suction lift).

Volumes indicated on chart were determined by actually pumping water into calibrated tanks.

AIR CONSUMPTION (SCFM)

AIR SUPPLY PRESSURE (PSIG)

DISCHARGE HEAD

WATER DISCHARGE — FLOW RATES

CERTIFIED DIMENSION DRAWING MODEL M4®

CAST IRON STAINLESS STEEL & HASTELLOY HAVE 1¼" NPT (FEMALE) DISCHARGE

ALUMINUM
1¼" NPT (MALE) DISCHARGE

EXHAUST

¾" NPT AIR INLET

1½" FEMALE INLET

FRONT VIEW

¾" NPT FEMALE AIR EXHAUST

Air Inlet

SUCTION

SIDE VIEW

Footed Base
Stainless Steel/Hastelloy

Base Drawing
Aluminum/Cast Iron
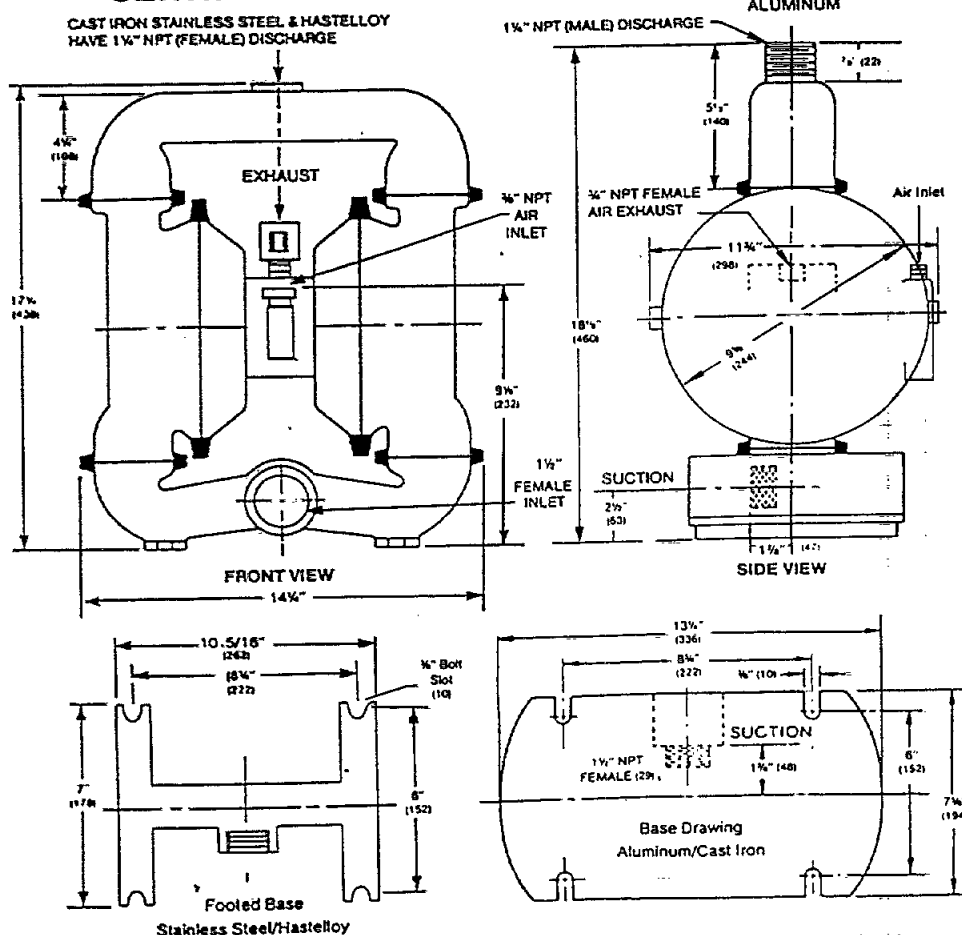
NOTE: Suction and discharge nipples on standard aluminum pumps are mild steel and on alloy-fitted aluminum pumps are stainless.
NOTE: Nipples are cast in and cannot be removed. All other models have female connections threaded into the casting.
NOTE: Models M4/SG and M4/SN have 2" standard tri-clamp style fittings.
O.D. — 2.516"   I.D. — 1.625"

AR309203

A-16

( ) Millimeters

APPENDIX

HAZARDOUS AREA CLASSIFICATION

MEMORANDUM

SUBJECT: Hazardous Area Classification

PROJECT: Boarhead Farms, Upper Black Eddy PA

If concentration calculations are necessary, a chemist will need to get involved because I'm not sure how to do them. Some facts I do know are:

1. The influent volatile organics are measured in parts per billion (ppb) of a liquid and NFPA 325M list chemical's lower explosive limit (LEL) in percent of vapor in the air. As you can see we are talking apples and oranges.

2. The proposed treatment process is a closed pipe system, therefore the water with the volatile organics will not be exposed to air. If the water is not exposed to air and the temperature is not at its flash point the volatile organic will not vaporize.

I conclude that because the influent has a small concentration of volatile organics, even if you add all the organic concentrations together, and the fact that the system is closed loop not enough organics will vaporize to create a hazardous area.

Although, natural ventilation or a small about of forced ventilation should be provided in the event that some vaporization does occur. If no ventilation is provided over several months the concentration may eventually reach a dangerous level.

Kevin Thernes
Electrical Engineer

A-18

PROJECT Boarhead Farms		SHEET NO.	OF
ITEM NFPA 325M		BY	DATE
		CHKD. BY	DATE

	Flash Point °F	AIT °F	LEL	UEL	Vapor density
Acetone	-4	869	2.5	12.8	2
Chloro methane (methyl Chloride)	135	N/A	7.5	18.5	3.8
Ethyl benzene	70	810	0.8	6.7	3.7
Methylene Chloride	none	1033	13	23	2.9
1,1-Dichloroethene (Vinylidene Chloride)	-19	1058	6.5	15.5	3.4
1,1-Dichloroethane (Ethylidene Dichloride)	2	N/A	5.4	11.4	N/A
Cis-1,2-Dichloroethene	36	860	5.6	12.8	3.4
1,1,1-trichloroethane	none	N/A	7.5	12.5	4.55
Trichloro ethylene	none	788	8	10.5	4.5
Benzene	12	928	1.2	7.8	2.8
1,1,2-Trichloroethane	?				
Tetrachloroethene	?				
Toluene	40	896	1.1	7.1	3.1
Vinyl chloride	-108.4	882	3.6	33	2.2
Xylene (o-xylene)	90	867	0.9	6.7	3.7
Carbon Disulfide	-22	194	1.3	50	2.6
2,4-Dichlorophenol	23.7	N/A	N/A	N/A	5.6
Carbon tetrachloride	?				
Napthalene	174	979	0.9	5.9	4.4
1,2-Dichloroethane	56	775	6.2	16	3.4

MRO Form 1550, 1 DEC 83

AR309206

☆ U.S.G.P.O.: 1993-556-577

APPENDIX

RECORD OF CONVERSATIONS

A -20

RECORD OF CONVERSATION

Point of Contact:	**Telephone: (402) 221-7685**
Jim Woolcott	**FAX:**
	Date: 24 May, 1996
Name and Organization:	**By: Janelle Mavis**

USACE, Omaha District Industrial Hygenist

SUBJECT: Emergency Eye Wash and Shower Units

Project: Boarhead Farms, PA

Applicable Regulations 29 CFR 1910.151 Part C and ANSI Z 358.1

Design and Specs in accordance with ANSI Z 358.1

(1) Emergency eye wash/shower can be plumed or self-contained units

(2) Eye wash flow required to be 0.4 gpm for 15 min or 6 gallon capacity

(3) Shower flow required is 20 gpm for 15 min or 300 gallon capacity (Para ANSI Z 358.1 - E5.1)

(4) The temperature of the water must be tempid or tolerable. Our building shall be maintained between 50 to 90 deg F.

  - Per IH no need for tempered water

(5) A sign per para 4.6.2 is required that designates the location of the emergency units.

(6) Follow the ANSI std for the water additives for the eye wash unit and shower.

(7) The std does not specify a maintenance schedule for self-contained units. Specify good engineering judgment for the O&M monitoring and schedule.

(8) The location of the units shall be 100 ft or 10 seconds.

CONDITIONS FOR EMERGENCY UNITS

When the facility has a corrosive material that may be spilled. Boarhead may have acid storage involved. Include a claus in the specs that the emergency eye wash/shower requirement shall only be necessary if there will be a corrisve material located on site that may be spilled.

A-21   AR309208

RECORD OF CONVERSATION

Point of Contact: Patrick Dorn Name and Organization:	Telephone: (708)543-9444 FAX: (708) 543-1169 Date: 2 May, 1996 By: Janelle Mavis

Great Lakes Environmental Inc.

SUBJECT: Packaged Chemical Precipitation Units

Project: Boarhead Farms, PA

He is sending me a package in the mail with all of the information we discussed on the phone.

Estimated chemical costs per year = $10,000
Estimated capital cost = $130,000 to $140,000

  The package would include: pH adjustment, chemical feed pumps and monitors, clarifier, filters, final pH adjustment, pumps

He stated that he supplied a packaged chem precip unit to Crab Orchard, IL Fluorel Danial Designed the system. Currently the operator is on site 2 or 3 days a week to optimize the system. He anticipates only having an operator on site 1 day a week after the starup is completed.

A-22

RECORD OF CONVERSATION

Point of Contact: **Telephone:** (412)772-0044

           Jim Krizner   **FAX:** (412) 772-1360

                                          Date: 7 May, 1996

Name and Organization: **By:** Janelle Mavis

           Lancy Environmental

SUBJECT: Packaged Chemical Precipitation Units

Project: Boarhead Farms, PA

We discusssed Lancy's packaged chemical precipitaion units.

He suggested either the SULFEX Process or the Sorption Filter Process

Capital Cost SULFEX = $200,000 to $250,000 with all the neccessary equipment except VOC removal and sludge handling - pH = 9.0

Estimated Chemical Costs = $9 to 10 thousand per year

Capital Cost Sorption Filter = $150,000 however iron will interfere with the process must run at a pH = 11 to 11.5

A-23

RECORD OF CONVERSATION

Point of Contact:	**Telephone:** (708)543-9444
Patrick Dorn	**FAX:** (708) 543-1169
	Date: 20 May, 1996
Name and Organization:	**By: Janelle Mavis**

Great Lakes Environmental Inc.

SUBJECT: Packaged Chemical Precipitation Units

Project: Boarhead Farms, PA

Mr. Dorn stated that the clarifier removes an estimated 96 to 97 % of solids.

He stated that downstream of the polishing filters - estimated 5 to 60 ppm of TSS leaving the filters.

We discussed his TPF-24-3 unit that is rated for 50 gpm. The required surface area is 9.4 sqft. The surface area per vessel is 9.4/3 = 3.13 sqft. The backwash flowrate of 30 gpm divided by 3.13 sqft per vessel = 9.6 gpm/sqft backwash flowrate.

The estimated hydraulic loading rate is 4 to 5 gpm/sqft = 75 gpm / 4 or 5 = 15 to 19 sqft required. For 3 vessels this is 5 sqft per vessel. The backwash could be 50 gpm per vessel (50 gpm/5 sqft = 10 gpm/sqft) for 8 minutes.

A-24

RECORD OF CONVERSATION

Point of Contact:	**Telephone: (412) 772-0044**
Jim Hauff	**FAX:**
	Date: 20 May, 1996
Name and Organization:	**By: Janelle Mavis**
Lancy Environmental Inc.	

SUBJECT: Polishing Pressure Filters

Project: Boarhead Farms, PA

We discussed Lancy's pre-packaged filter units. They can be fabricated according to the specifications in any piping arrangement.

(1) Lancy has down-flow pressure filters or Upflow filters

(2) Jim Hauff did not recommend upflow filters downstream of the clarifier because potential clogging.

(3) Recommended hydraulic loading rate 4 to 6 gpm/sqft

(4) Recommended backwashing rate 10 to 15 gpm/sqft for 10 to 15 minutes.

Consider the difference between a 2 or 3 filter system versus the size of the units and the backwashing volume of water needed.

Look at the effluent storage tank as the source of the water for the backwashing.

RECORD OF CONVERSATION

Point of Contact:

Jim Johnson

Name and Organization:

J.D. Anderson, Inc.

SUBJECT: Plate Filter Press

Project: Boarhead Farms, PA

Telephone: (612) 721-1721
FAX:
Date: 4 May, 1996
By: Janelle Mavis

Estimated TSS off sludge holding tank = 50 ppm

Estimated flowrate to press = 20 gpm initially. As the press fills the flowrate decreases. The filtrate will equal the influent flowrate.

Estimated 8 cubic foot unit with sludge pump.

Capital Cost = $18,200 (doesn't include sludge disposal costs)

Footprint = 30 " W x 10'L x 4' H need access to one side only for sludge cake removal

When the press is full a remote dialer can notify the operator. The operator presses a button and the press opens and the cake falls out. The operator presses a button and the press closes.

The press has integral safety switches - will not over pressurize the press.

Utility requirement - 220 V 1 HP motor to open/close door
     ADP pump
     **Add air source to sludge tank

Recommended talking with local rep. Jim McFarland or Roger Gailhouse
       Mc2 333-9860

A - 26

From: Janelle M Mavis
To: MRO01-FC.MROCD-FC.CDFCWWS, MROED-E.EDEDTLS, EDDKRL...
Date: 5/9/96 4:11pm
Subject: Boarhead Conf. Call with EPA

Thurs 8 May 96 Conference call with EPA.
Participants:
Jim Harper EPA RPM
Wally Shaheen TM
Janelle Mavis
Delma Stoner
Items discussed:

(1) EPA agreed with the non-hazard rating in the treatment building.

(2) EPA agreed with the proposed treatment train of chemical precipitation and air stripping with liquid carbon a polishing.

(3) EPA stated that off-gas treatment from the stripper is not required at this time. EPA stated that if needed they will modify the plant in the future to incorporate the treatment.

(4) EPA agreed with the process operation as a batch mode with 100 % increase in capacity if the plant was operated 24 hours a day instead of 12 hours a day.

(5) EPA suggested looking at a "Filter Sock" versus a plate filter press. Jim gave me a P.O.C. with CLean Harbors to call about the equipment.
Mr. Jack Maserejian (617) 849-1800 ext 1144. EPA has experience with this equipment at Strausburg Landfill project.

(6) EPA agreed with the redundant pumps in the system.

(7) EPA ACtion item: (a) To identify the pounds of VOC that can be discharged into the air per year (b) Where to sample for compliance - at the boundary of the site or at the stripper discharge point

Janelle Mavis

CC: EDDKJMM

A-27

Cation Selectivity
8% DVB Crosslinking

Counter Ion	Selectivity
Hydrogen (+1)	1.00
Sodium (+1)	1.56
Copper (+2)	2.03
Magnesium (+2)	2.59
Zinc (+2)	2.73
Cadmium (+2)	3.06
Nickel (+2)	3.09
Calcium (+2)	4.06
Lead (+2)	7.80
Barium (+2)	9.06

QUICK FAX OfficeMax

Date:	# Of Pages:
To: JANELLE MAVIS	From: Bruce Weaver
Co./Dept.	Co./Dept.
Fax: 402-221-3842	Fax:
Phone:	Phone: 612-678-1332
Note:	E-Mail:

A - 28

AR309215

CONVERSATION RECORD

TIME	DATE
1110	16 Apr 96

TYPE

☐ VISIT   ☐ CONFERENCE   ☐ TELEPHONE

☐ INCOMING   ☒ OUTGOING

ROUTING

NAME/SYMBOL	INT

Location of Visit/Conference:

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO:
Dar Soder	Culligan	397-4234

SUBJECT

Ionization of constituents found in the groundwater @ Boarhead Farms, PA

SUMMARY

Ion exchange alone is not feasible. & the effluent requirements would not be met

VOC: SVOC need stripping tower, carbon or combination of the two for removal

Iron; Manganese - needs to be addressed first - need to be removed before any other treatment process can occur - may need flocculation; sedimentation then filters

ACTION REQUIRED

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE
Nancy Pridal	Nancy Pridal	16 Apr 96

ACTION TAKEN

SIGNATURE	TITLE	DATE

A-29   AR309216

CONVERSATION RECORD

	TIME	DATE
	1625	15 Apr 96

TYPE

☐ VISIT ☐ CONFERENCE ☒ TELEPHONE

☐ INCOMING ☒ OUTGOING

Location of Visit/Conference:

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU

Tony Bilek

ORGANIZATION (Office, dept., bureau, etc.)

Baines & Associates

TELEPHONE NO.

895-6336

SUBJECT

Ionization of constituents found in the ground water @ Boxhead Farms, PA

SUMMARY

- would have to be air stripped before a ionization column would work.

- large volume of concentrated water due to large volumes of resins would need further treatment

- air stripping would be required to remove the VOC's before ionization would be feasible

Mr. Bilek was faxed a copy of the treatment requirements for the VOC's and Inorganics which included the expected influent and Effluent Requirements

ACTION REQUIRED

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE
Nancy Pridal	Pridal	9/15/96

ACTION TAKEN

SIGNATURE	TITLE	DAT

50271-101   * U.S. GPO: 1988-201-748/46170   (40231) CONVERSATION RECORD   A-30

AR309217

Phone Conversation Record

Person Called:	**Norm Abbott**	Filename:
Company:	**Raines & Associates**	c:\jan\boarhead\roc\ionroc1.doc
Phone :	(402) 895-6336	
Fax:	(402)895-5324	

Person Calling:	Janelle Mavis
Date:	25 Apr 96

Subject: Ion Exchange

(a)   Hexavalent Chromium and Trivalent Chromium are both adsorbed

(b)   When the resin is exhausted it can be regenerated by acid or caustic. The wastewater generated will require further treatment to reduce the volume before disposal or direct disposal, if the volume are acceptable.

(c)   An ion selective resin can be chosen. This resin will only adsorb the "heavy" metals in solution: Cadmium, calcium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, zinc. There may be a large amount of interference with other ions to just remove a small amount of cadmium or chromium.

(d)   Would need to monitor conductivity or resistivity to determine when the resin was exhausted.

(e)   The solid resin beads cost about $200 to $250 / cft

(f)   The resin exhausted limit is about 2 pounds of metals per cubic foot of resin.

(g)   Regeneration takes about 75 to 100 gallon/cft of resin. A 36" diameter by 36" bed depth has approx. 21 cft of resin therefore 2,100 gallons per regeneration period.

(h)   The maximum hydraulic loading rate is 10 gpm/sqft

(I)   Regeneration water treatment options:
- evaporation
- chemical precipitation

We discussed Reverse Osmosis. The drawback is the waste stream of about 10 % to 35 % of the flowrate depending upon the efficiency of the R.O. unit.

RECORD OF CONVERSATION

Point of Contact: ·**Telephone:** (612) 638-1300
　　　　　　　　Bruce Weaver　　**FAX:** (612) 633-5074
　　　　　　　　　　　　　　　　　　Date: 3 May, 1996

Name and Organization:
　　　　　　　US Filter
　　　　　　　Mps, MN

SUBJECT: Ion Exchange to Treat Metals without Pre-treatment for metals only
　　　　　　　　VOC Pre-Treatment

Cation Exchange Resin	Anion Exchange Resin
Cobalt	Chromium
Copper	Chloride
Iron	Sulfates
Cadmium	
Nickel	
Zinc	

(a)　　US Filter rents the ion exchange units. Cation unit monthly rate = $608 - Anion unit monthly rate = $300. Regeneration costs per 30 cuft unit: Cation regen = $2580 and anion regen = $3450. Transportation costs from PA to MN about $8000 round trip.

(b)　　US Filter can not treat F001- F005 listed wastes with ion exchange.

Resin Usage Rate estimated by vendor

Both a cation resin unit and a anion resin unit would be required to treat the for cadmium and chromium.

- The cation unit has an estimated life for a 30 cuft resin unit of 1 to 2 weeks - estimate 52 changes per year

- The anion unit has an estimated life for a 30 cuft resin unit of 12 hours, 2 changes per day or 730 changes per year.

ESTIMATE:

12 months rental cation unit =	$7,300
12 months rental anion unit =	$3,600
cation changes per year = 52	
regen cost = (52*2580)=	$134,160

AR309219

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```
       anion changes per year = 730
           regen cost = (730*3450)=        $2,518,500
       Transportation for 200 trips=       $160,000
```
TOTAL COST FOR ION EXCHANGE= $2,753,900
WITHOUT ONSITE REGENERATION

Recommend on site regeneration. This would generate a wastewater regenerate stream that would be treated with chemical precipitation or some other means.

(1) VOC's must be removed prior to ion exchange. The VOC's destroy the resin's capability to adsorb metals. In fact U.S. Filter will not accept the resin for regeneration becuase their regeneration plant is not equipt to handle the VOC's desorbed during regeneration.

(2) Their is a sodium chelating resin available that will remove cadmium. It also removes other ions such as coper, zinc, nickel etc.

(3) Their are ion selective resins available for the removal for zinc, copper, and nickel. Their are no ion selective resins available that will strictly remove cadmium or chromium.

(4) If a resin was chosen to remove calcium, the cadmium would be "kicked off" because of the selectivity of the resin. The selectivity is based on the ionic strength of the divalent ions. The higher the ionic strength of the compound the stronger the adhering foreces to the resin.

(5) Hardness may be a problem with blinding the resin or fouling/sclaing probelms. Bruce recommended hardness removal prior to the ion exchange.

(6) He faxed me a selectivity table that show which compounds will adhere to the resin first and which ones will "kick off" lower ionic strength ions.

A - 33

Ion Selective Resin ie. Chelating-Resin. Heavy Metals will be adsorbed onto this resin. Determine the feasibility of ion exchange based on the amount of regeneration water that needs to be directly disposed of or treated to reduce the volume before disposal.

Example

mg/L * g/1000 mg * lbs / 454 grams * 3.785 liters/gallon = lbs Metal /gallon treated

flowrate = ▓▓▓▓▓55▓ gpm

ANIONS ONLY

Contaminant	Influent mg/L	Lbs/gallon
Chromium	0.1	8.3E-07
Chlorides	18	0.00015
Sulfates	400	0.003335

Total lbs heavy metals per gallon of treated g 0.003486 pounds

Resin used per the flowrate =   0.191714 lbs/min   (flowrate times lbs/gal)

Per Raines & Associates POC Mr Norm Abbott

Ion Selective Resin has an adsorptive limit of 2 lbs of metals per cubic foot of resin.

Time to reach resin adsorptive limit (2 lbs) =   10 minutes/ cft

Example

21 cft resin bed regenerate every   4 hours

Regeneration rate of 75 to 100 gpm / cft resin

Total regenation water =   12600 gallons/ 24 hr day

Must treat this water to reduce the volume for disposal by:
- (a) Evaporation
- (b) Chemical Precipitation

A-34

AR309221

Ion Selective Resin ie. Chelating-Resin. Heavy Metals will be adsorbed onto this resin. Determine the feasibility of ion exchange based on the amount of regeneration water that needs to be directly disposed of or treated to reduce the volume before disposal.

Example

mg/L * g/1000 mg * lbs / 454 grams * 3.785 liters/gallon = lbs Metal /gallon treated

flowrate = 55 gpm

CATIONS ONLY

Contaminant	Influent mg/L	Lbs/gallon
Cadmium	0.014	1.2E-07
Cobalt	0.06	5E-07
Copper	0.02	1.7E-07
Iron	37	0.000308
Lead	0.003	2.5E-08
Mercury	0.001	8.3E-09
Nickel	0.12	1E-06
Zinc	0.03	2.5E-07

Total lbs heavy metals per gallon of treated g 0.000311 pounds

Resin used per the flowrate = 0.01708 lbs/min (flowrate times lbs/gal)

Per Raines & Associates POC Mr Norm Abbott

Ion Selective Resin has an adsorptive limit of 2 lbs of metals per cubic foot of resin.

Time to reach resin adsorptive limit (2 lbs) = 117 minutes/ cft

Example

21 cft resin bed regenerate every 41 hours

Regeneration rate of 75 to 100 gpm / cft resin

Total regenation water = 1575 gallons/ 24 hr day

Must treat this water to reduce the volume for disposal by:
  (a) Evaporation
  (b) Chemical Precipitation

Notes: Depending upon how much iron is adsorbed onto the resin. The iron may or maynot depending upon the resin.

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Contaminant	Influent Ci (mg/L)	Effluent Ce (mg/L)
1,1-Dichloroethene	0.03	0.007
cis-1,2-Dichloroethene	0.25	0.07
1,1,1-Trichloroethane	1	0.2
Trichloroethene TCE	6	0.005
Benzene	1	0.005
Tetrahloroethene PCE	0.15	0.005
1,1-Dichloroethane	0.05	0.004

Plant Flowrate gpm = ▓▓▓▓ gpm

AOP = Advanced Oxidation Process
(UV/OX with Hydrogen Peroxide)

Description	Air Stripping/ Carbon	AOP UV/OX with H2O2	
Capital Equipment	$38,800	$113,000	($19,000 Tray Aerator)
Installation & Startup	$10,000	$10,000	
Total Capital Cost	$48,800	$123,000	
Utilites cost/yr	$5,800	$62,415	
Carbon Replacement	$12,000	$0	
Lamp Replacement	$0	$7,884	
Chemical/ yr	$500	$5,500	
Labor Costs/yr	$4,680	$7,800	
Depreciation/yr	$9,760	$24,600	
O&M Total / yr	$32,740	$108,199	
Cost/1000 gallons	$1.66	$5.49	

Notes:

(1) Operating Continuous for 9 months
(Estiamted gallons per year)   50 gpm * 1440 m/d * 365 d/yr * .75 * 1/1000 =   19,710   1000 gal/yr

(2) Electrical Cost = $0.10 / KW/hr * 365 d * .75 *24 hr/d * 95kW (UV/OX)
(3) Electrical Cost = $0.10/kW/hr *365d * 24hr/d * .75 * kW (Air Stripping)
(4) Carbon Cost = $ per pound Estimated Carbon usage per year =
(5) Lamp Replacement Every 3000 hrs operation. 6 lamps * $600/Lamp * 365d *24.75*1/3000
(6) Chemical Costs (Air Stripping) $1000 for acid washing/cleaning
(7) Chemical Costs (UV/OX) Hydrogen Peroxide = $2.50 / gallon Est H2O2 Usage / yr =2200 g
(8) Labor Costs = 5 hrs per week for 9 months at $40.00 /hr UV/OX
(9) Labor Costs = 3 hrs per week for 9 months at $40.00 / hr Air Stripping
(10) Straight Line Depreciation - Capital Costs + Salvage Value / Years in Operation
(11) Slavage values = $0.00 for both Years of Operation = 5 for both

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A-Better Earth

8113 Woodstone
Lenexa, KS 66219
PH 913-888-0024
FX 913-888-8566

To: _Janelle Mavis_

From: _Gunnar L. Peterson_

Fax: _402 221 3842_

Pages: _____

Date: _4/17/96_

UV/OX
discussion

RE: UV Oxidation

We have reviewed the application utilizing UV Oxidation and we came up with two options. During our review we took the following assumptions:

- Metals removal will be accomplished before the UV system.
- The TDS is a little high at 690 ppm, although we suspect that with chemical metals removal system the level will drop.

Assuming the above the remaining organic are generally easy to treat with the exception of saturated chloro alkanes: TCA and DCA. Consequently, we would assume that the system would fully treat all organic except these compounds.

For your application we would select the Solox Wastewater Purification system Model SE3 40kW UV system or the SE3 95kW system. The Effluent of the UV Oxidations system are as follows:

Contaminant $\mu g/l$	Influent $\mu g/l$	Eff. 45kW	Eff 95kW
1,1 DCE	30	<<1	<<1
cis 1,1,2 DCE	250	<<1	<<1
111 TCA	1000	500	200
TCE	6000	1	<<1
Benzene	1000	<<1	<<1
PCE	150	<<1	<<1
1,1 DCA	50	15	3

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Costs for the UV Oxidation system are as follows:

Capital equipment cost

40kW system	$75,000.00
95kW system	$113,000.00

For each of the above systems a performance warranty can only be provided when we execute a treatability test. The test requires 55 gallons of waste and costs 2,500.00, which will be deducted from the equipment price.

Installation cost

The installation costs for a UV system are no greater than an Air stripping system, and simpler than an Air stripper system with off gas treatment.

Peroxide

For both systems we would assume a 50% concentration of hydrogen peroxide, $2.50/gallon, and 50 ppm loading. The exact loading can be established during the treatability test(anticipated range 25 to 75ppm). The $2.50 cost for peroxide is based on large volume purchases, (by the truck or part truck load rather than by the drum).

Peroxide Demand: 2190 gallons or $5,475.00/yr, or $.20/1000 gallons.

Electrical Costs

40kW system = 40kW X 8760 hr/yr X $0.10/kWhr = $35,040.00 or $1.33/1000 gallons.

95kW system = 95kW X 8760 hr/yr X $0.10/kWhr = $83,320.00 or $3.17/1000 gallons.

Lamp Replacement Costs

For each system the first lamp replacement is included with the system.

40kW system = (8760 hr/yr / 3000hr) X $600.00/lamp X 3 lamps = $5,256.00/yr, or $0.20/1000 gallons.

95kW system = (8760 hr/yr / 3000hr) X $600.00/lamp X 6 lamps = $10,512.00/yr, or $0.40/1000 gallons.

If you have any question call at 800 386 5134

Sincerely,

Gunnar L. Peterson
President

AR309225

SOLOX
WASTEWATER REMEDIATION SYSTEMS ®
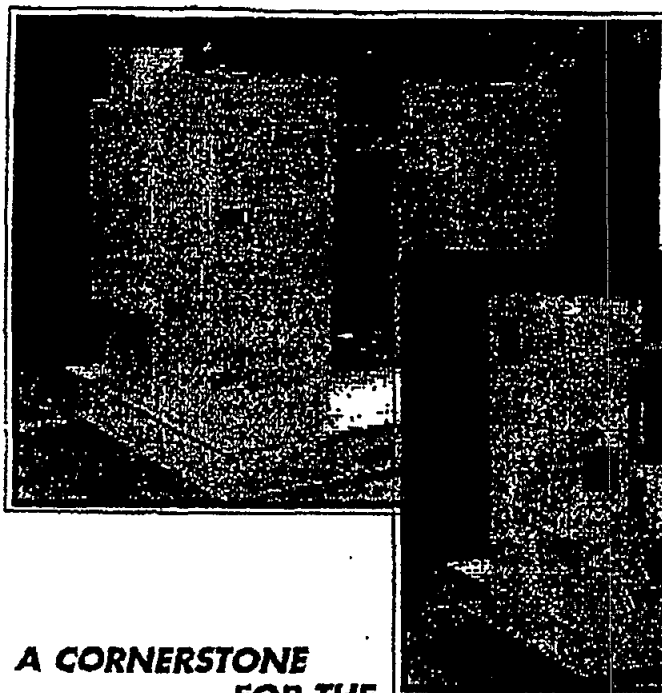
GROUNDWATER TREATMENT SYSTEMS

A CORNERSTONE FOR THE PUMP & TREAT INDUSTRY

The SOLOX process destroys organic contaminants at the site, in the water: no disposal costs and no air permits.

Ultraviolet light and hydrogen peroxide break toxic pollutants into benign compounds, carbon dioxide, water, and trace salts.

Robust simplicity is the guiding design principle of all SOLOX equipment. The compact modular equipment skids require no operator attention and minimal maintenance.

A sample of groundwater can be tested by SOLOX to establish the destruction rates, equipment size, and operating demands of your water matrix.

SOLOX is a division of SKI, a company with 22 years of experience in customer satisfaction.
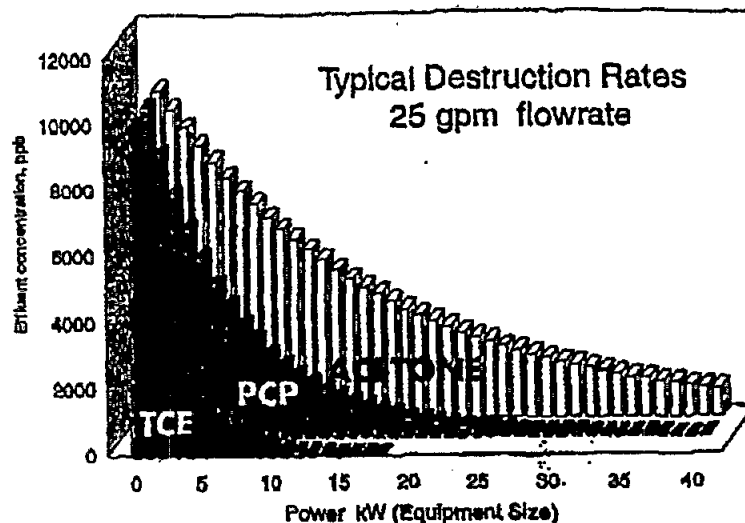
SOLOX Division   (800)969-7654
10635 King William Dr. Dallas, TX 75220   Fax (214)869-4168
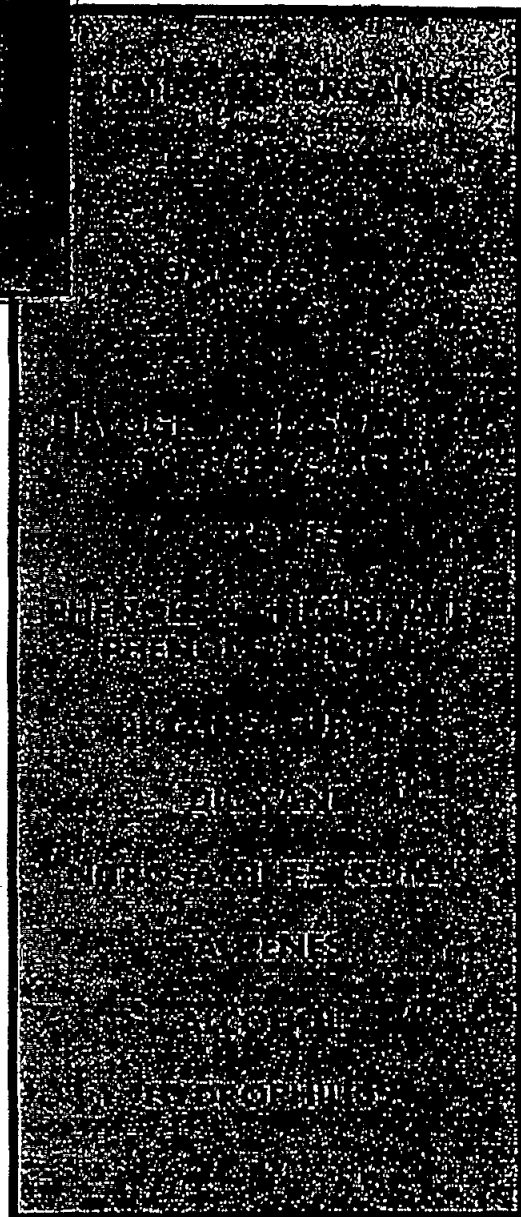
UV oxidation is a first order process: the destruction rate is logarithmic. Each contaminant has different rate constants. Destruction of several contaminants generally proceeds in parallel. The total power demand is defined by the organic with the slowest rate, not the sum of power requirements.

Inorganics and background organic contaminants affect destruction. A treatability test is recommended for all applications. All costs associated with lab testing are deducted from the equipment sales price.

Typical Destruction Rates 25 gpm flowrate

Effluent concentration, ppb — Power KW (Equipment Size)
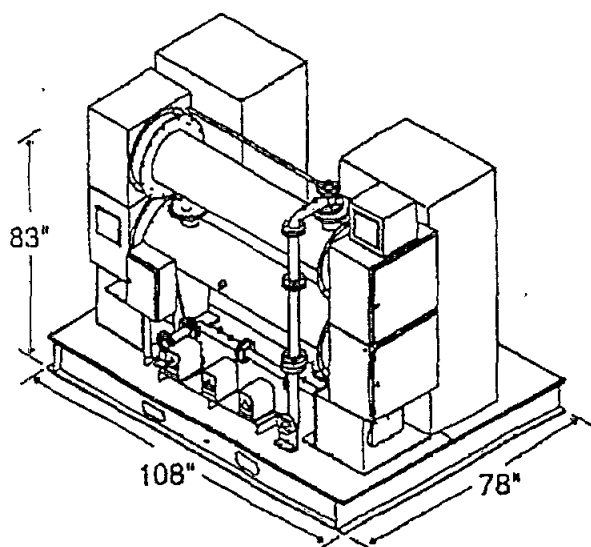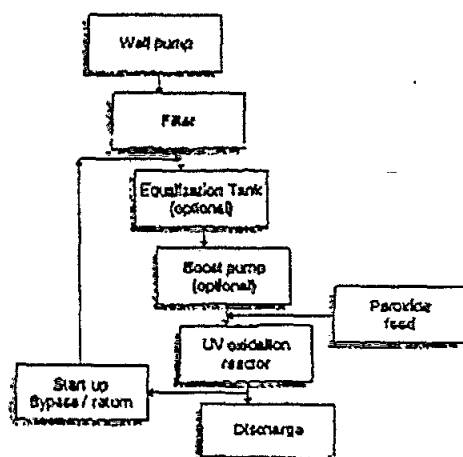
TCE   PCP   ACETONE

RELATIVE PERFORMANCE

Peroxide is metered into filtered groundwater, homogenized in a static mixer, and sent to the reactor. In some cases, an equalization tank and boost pump are used to even concentration.

The stainless ultraviolet reactor operates at pressures from atmospheric to 50 psi, with flow rates ranging from a few gallons per minute to hundreds of gallons per minute. High intensity UV lamps effect the oxidation reaction. The lamps can be sized for specific applications and operated at power levels to match the required destruction. Clarity is maintained with a patented wiper system.

All equipment is regulated by a logic controller in response to on-board sensors. The complete system is assembled, skid mounted, and tested before shipment.

TYPICAL FLOW SCHEMATIC   BASIC FOOT PRINT

Well pump
Filter
Equalization Tank (optional)
Boost pump (optional)
Peroxide feed
UV oxidation reactor
Start up Bypass / return
Discharge

83"
108"   78"

SOLOX
WASTEWATER REMEDIATION SYSTEMS ®

a division of Solar Kinetics, Inc.
10635 King William Drive, Dallas, TX 75220 800-949-7654

AR309227

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1. General

1.1 Scope

1.1.1 This specification defines the requirements for an Ultraviolet (UV) Oxidation system. That system includes reactors, power supplies, power distribution, oxidant storage, oxidant feed, and process control. All equipment shall be fully assembled, plumbed, wired, skid mounted, and tested.

1.1.2 The UV Oxidation system shall be designed to oxidize the contaminants identified in Table 1.1.

Table 1.1 Design conditions

Design flow rate	__ gpm	
	Influent concentration ppb	Effluent concentration ppb
Organic contaminants		
Contaminant # 1		
Contaminant # 2		
Contaminant # 3		
Inorganic contaminants		
Contaminant #4		na
Contaminant #5		na

1.2 Performance and warranty

1.2.1 The UV oxidation system manufacturer shall warrant all furnished equipment to be free from defects in materials and workmanship for twelve months from the date of shipment.

1.2.2 The manufacturer shall guarantee that the equipment continuously meets the performance requirements described in section 1.1.2 for the warranty period.

1.3 Submittals and Delivery

1.3.1 The UV oxidation system manufacturer shall submit general arrangement drawings that include dimensions, weight, materials of construction, and installation instructions within four weeks of purchase order receipt.

1.3.2 A complete operating and maintenance (O & M) manual shall be provided on delivery of the equipment. The O & M manual will include information as required to maintain operator safety and equipment performance.

1.3.3 Spare parts and assemblies adequate for one full year of operation shall be provided with the UV Oxidation system. All spare parts shall be separately packaged and marked with the part number.

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1.4 Acceptable Manufacturers

1.4.1 The UV Oxidation system shall be manufactured by Solox, a division of Solar Kinetics, Inc. located in Dallas, Texas or an approved alternate.

1.5 Bid Requirements

1.5.1 The UV oxidation manufacturer shall specify the capital cost of all equipment and delivery charges to the site. An estimate of operating expense including power cost, all reagents, and consumable components shall accompany capital cost estimates.

1.5.2 Support required from the purchaser including reagent storage, secondary containment of reagents, utility requirements, maintenance access, and weather protection shall be provided by the UV system manufacturer with capital cost estimates.

1.5.3 Custom or specialized consumables that are provided only by the UV manufacturer or a severely limited number of vendors including, but not limited to, lamps and reagents must be specified by the UV system manufacturer with capital cost estimates.

2. Equipment

2.1 UV Oxidation System

2.1.1 The UV Oxidation system includes reactors, power supplies, power distribution, oxidant storage, oxidant feed, and process control.

2.1.2 All equipment shall be fully assembled, plumbed, wired, skid mounted, and tested at the factory prior to shipment.

2.1.3 All equipment shall be new. All system components must be cleaned and restored after final testing.

2.1.4 The UV oxidation system shall be suitable for installation on a sealed concrete floor in an industrial environment for operation between 40 and 95° F, non-condensing humidity.

2.2 UV Reactor

2.2.1 The UV reactor shall include a reactor vessel, one or more lamps, and a wiper assembly. All wetted materials shall be T304 stainless steel, quartz, Teflon®, Viton® or approved equal. All polymer materials must be protected from direct ultraviolet irradiation.

2.2.2 The reactor housing shall be capable of sustaining 100 psig operating pressure. Pressure relief shall be provided.

2.2.3 Ultraviolet lamps shall provide a minimum of 35% of their total output below 300 nm. Lamps shall be warranted for 3000 hours of operation.

2.2.4 The lamps shall be enclosed in a quartz envelope. Lamp removal and replacement must be accomplished without breaking any plumbed connection.

2.2.5 The wiper assembly shall continuously maintain the cleanliness and optical transmission of the quartz envelope. Wiper actuation shall be automatic.

2.3 Oxidant Feed System

2.3.1 The oxidant feed system shall include a hydrogen peroxide storage tank, metering pump, level indicator, and static mixer. All wetted materials shall be acceptable for concentrated oxidant service.

2.3.2 The hydrogen peroxide storage tank shall be manufactured from HDPE, covered, and provided with separate, valved fill and drain connections. The tank will be vented and designed to operate at atmospheric pressure.

2.3.3 The oxidant feed pump shall be factory calibrated for the appropriate feed rate. The oxidant flow rate shall be regulated by a process flow meter.

2.3.4 Provisions shall be made to provide automatic priming for the oxidant feed pump.

2.3.5 A static mixer shall be provided immediately after oxidant injection to insure a homogeneous process stream.

2.4 Interconnect Piping

2.4.1 Interconnect piping includes all plumbed connections and lines required between the influent and effluent connections of the UV oxidation system. Wetted materials shall be acceptable for contaminated water service. T304 stainless steel is required in all connections that are exposed to ultraviolet light.

2.4.2 Sample valves shall be provided to allow monitoring the influent and effluent water stream. A vent valve shall be provided at the system high point.

2.5 Power Supplies

2.5.1 The power supply shall be provided by the UV system manufacturer and include isolation transformers, capacitors, and circuit protection housed in a NEMA 1 enclosure.

2.5.2 Wiring must comply with the requirements of the National Electrical Code. All high voltage cabinets must be provided with safety interlocks. All high voltage lines must be routed through separate wireways.

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2.5.3 At full power, the power supply efficiency must exceed 92%; the power factor must exceed 0.92.

2.5.4 The power supply shall accept a single, 480 VAC, 3 phase power drop. A lockable disconnect switch must be provided as the service entrance. All system power shall be provided from this single drop.

2.6 Process Controls

2.6.1 The control system shall be provided by the UV equipment manufacturer and include a programmable logic controller (PLC), operator interface, and sensors housed in a NEMA 12 enclosure.

2.6.2 All wiring and components must comply with the requirements of the National Electrical Code and the Underwriters Laboratory.

2.6.3 The programmable logic controller must provide a stable memory that is unaffected by power loss. The controller should execute self-diagnostics, and identify any potential problems in program operation.

2.6.4 The operator interface shall provide switches to simultaneously or individually disable all electrical process components. A flow meter shall be used to regulate oxidant feed. Status, maintenance, and alarm conditions shall be visibly and audibly annunciated and must include:

     2.6.4.1.1 Operation normal
     2.6.4.1.2 Lamp and system operation hours
     2.6.4.1.3 Total treated volume
     2.6.4.1.4 Door interlock open
     2.6.4.1.5 Low flow rate
     2.6.4.1.6 Low oxidant level
     2.6.4.1.7 Lamp maintenance required
     2.6.4.1.8 Reactor high temperature
     2.6.4.1.9 Reactor leak detected

2.7 Optional Equipment

2.7.1 T316 material substitution (revise 2.2.1 and 2.4.1)

    2.7.1.1 All reactor and interconnect piping wetted materials shall be T316 or T316L stainless steel, quartz, Teflon®, Viton® or approved equal. All polymer materials must be protected from direct ultraviolet irradiation.

      2.7.1.1.1 Note: T316 and T316L materials are typically required only when the process water pH is low or reduced by an acid feed. Acid feed is required only for unusual process conditions or contaminants.

      2.7.1.1.2 Note: T316 materials increase UV oxidation equipment cost. These materials should not be specified unless process conditions demand their use.

2.7.2   Lamp power regulation

2.7.2.1   The UV manufacturer shall provide the means to alter lamp power output during equipment operation to respond to changes in process conditions (add to section 2.2).

2.7.2.2   The UV system process controls shall include a transducer that monitors lamp ultraviolet output. This information shall be available to the PLC (add to section 2.6).

2.7.2.2.1   Note: Lamp power regulation is typically required only on high powered systems (> 50 kW) or when flow rate vary widely. Active power regulation increases cost, and should not be specified unless process conditions require it.

2.7.2.2.2   Note: Lamp power can be regulated in SOLOX equipment without this option if the unit is temporarily turned off. This option is only required when power output must be actively regulated.

2.7.3   Remote operational control (add to section 2.6)

2.7.3.1   The UV system process controls shall include an autodialer. The autodialer will have the capacity to deliver facsimile messages describing alarm or maintenance requirements.

2.7.3.2   The process controls shall include a modem to allow remote diagnosis and system operational changes through access and revision of the PLC program and data storage.

2.7.4   Customized options

2.7.4.1   Alternate electrical enclosures, or equipment design for outside operation can easily be accomplished with the system.

2.7.4.2   The UV oxidation system can exercise pH control if required by the process.

2.7.4.3   The UV system can be combined with additional treatment components, equalization tanks, bypass valving, isolation valving, or other special needs of the client.

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Phone Conversation Record

Person Called:	Karl Kraus
	Calgon
Phone:	708-505-1919
Fax:	
Person Calling:	Janet Doan
Date:	March 28, 1996

Subject: Lower Profile Units and Other Metals

A lower profile unit is usually avoided because of the difficulty of getting the carbon in and out of the unit. Carbon has a high angle of incidence: carbon gets hung up on the sides. They make a lower profile unit (Model 12) which has cones which help to get carbon out. The Model 12 includes 2 units in series, each with 20,000 lbs of carbon. Cost is approximately $196,000 for Model 12 (includes initial fill). Some adjustments can be made to account for our flow: use 4" instead of 8" piping. If reactivated carbon is used, cost would be $172,000. Could design own vessels, but usually not cost effective over standard-type system.

Model 12 Size: 174" height (14.5 ft)
                   390" length (32.5 ft)
                   157" width (13 ft)
(Model 8 is 16' 4", area is 22' x 9.6')

I asked about other metals which could cause a problem in terms of disposal. (Reduces liability not to landfill.) Maximum amount which Calgon can accept (mg/kg).

Arsenic	15
Barium	170
Cadmium	85
Cobalt	35
Copper	220
Lead	10
Manganese	380
Nickel	285
Selenium	135
Silver	5
Strontium	5
Zinc	30

Question need to ask: What percent of these metals will the carbon take up (was 2% for arsenic).

c:\...\calgon3.wpd

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AR309233

RECORD OF CONVERSATION

Point of Contact: **Telephone:** (708) 505-1919

        Karl Krouse   **FAX:** (708) 505-1936

                                       Date: 2 May, 1996

Name and Organization:

        Calgon

SUBJECT: Liquid and Vapor Phase GAC (costs)

Vapor Phase Units   Using Less Stringent PA Water Quality Effluent Requirements

(1)   Base on EZ Tray VOC effluent numbers it will take about 0.21 lbs/hr divided by 20% - 1.05 lbs / hr * 12 hr = 13 lbs per day   Say 15 lbs per 12 hr day vapor phase GAC usage

         Per FAX from "A Better Earth" Tray aerator purchase price = $17,000

(2)   Per Karl Krause a VAPOR PAC 1800 lbs carbon would be the best size for changing out the entire unit and transporting to the carbon regeneration facility.

         - Polyethylene Vapor GAC purchase price = $9400 per unit ($18,800)
         - Refill of carbon cost = $1800 per unit
         - Transportation Cost = $1200 rt per changeout

OPTION 1: Tray Aerator plus Vapor Phase Carbon Treatment

1800 lbs carbon divided by 15 lbs/d = 120 days life of vessel   Say 3 changeouts per year

Capital Cost =	$18,800
Refill Cost (3 * 1800) =	$ 5,400
Transportation Cost (3*1200)=	$ 3,600
Carbon Only Sub- total =	$27,800 Carbon Only
Tray Aerator Capital Cost=	$17,000
Electrical Cost =	$ 5,800
TOTAL COST PER YEAR =	**$50,600 For this Option**

Liquid Phase Units

(3)   Based on converstation with Karl Krause and Calgon Carbon usage rate of 83 lbs per day for liquid GAC only, no stripping first.

- 85 lbs / 24 hr day * 365 d = 31,025/2 lbs per 12 day per year = $15,500 lbs
- Use small 2000 lb units that can be delivered on site with new carbon rather than the large 10,000 lb units
  - 2000 lb unit will last about 6 to 7 weeks, therefore 8 vessel changes / year
  - 2000 lb unit purchase price = $15,200
  - Refill fee = $2400
  - Rental Costs
    Initial fee = $2400 + $355 / month + refill $2400 + transportation
  - Transporation Costs = 600 mi * $2 / mi = $1200 / trip

OPTION 2: Liquid GAC Only (SMALL 2,000 LB UNITS)

Capital Cost (2 units)=	$30,400
Refill Costs (8*2400)=	$19,200
Transportation (8 * 1200)=	$ 9,600
TOTAL COST LIQUID GAC =	**$59,200 for this Option**

OPTION 3: Liquid GAC Only (LARGE 10,000 LB UNITS)

<u>Support Equipment Required</u>: 9,000 gal Effluent Storage tank used for changeout purposes, backwash pumps 100 gpm, access road and turn around requirements

(From Previous ROC)

Capital Cost (2*$87,000) =	$174,000
Carbon Change out (1*9000)=	$ 9,000
Transportation (1 * 1200)=	$ 1,200
Support Equpiment =	$50,000 +
TOTAL COST LIQUID GAC =	**$234,200 + for this Option**

Using Most Stringent (MCL) Effluent Requirements:
** Liquid Carbon Usage rate = 1500 lbs/24 hr day Therefore for 12 hr day use 750 lbs/12 hr/ day

** Vapor GAC required = 0.3 lbs per hour * 12 hours = 3.6 lbs per 12 hrs day divided by 20% = about 18 lbs per 12 hour day

<u>Say 20 lbs VGAC per 12 hour day</u>

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OPTION 1: Tray Aerator plus Vapor Phase Carbon Treatment

1800 lbs carbon divided by 20 lbs/d = 90 days life of vessel   <u>Say 4 changeouts per year</u>

Capital Cost =	$18,800
Refill Cost (4 * 1800) =	$ 7,200
Transportation Cost (4*1200)=	<u>$ 4,800</u>
Carbon Only Sub- total =	$30,800 Carbon Only
Tray Aerator Capital Cost=	$20,000
Electrical Cost =	<u>$ 5,800</u>
TOTAL COST PER YEAR =	**$56,600 For this Option**

OPTION 2: Liquid GAC Only (LARGE 10,000 LB UNITS)

<u>Support Equipment Required</u>: 9,000 gal Effluent Storage tank used for changeout purposes, backwash pumps 100 gpm, access road and turn around requirements

10,000 lbs / 750 lbs/12hr d = 13 days   Changeout both units once a month or 12 times

(From Previous ROC)	
Capital Cost (2*$87,000) =	$174,000
Carbon Change out (12*9000)=	$108,000
Transportation (12 * 1200)=	$144,000
Support Equpiment =	<u>$50,000 +</u>
TOTAL COST LIQUID GAC =	**$476,000 + for this Option**

RECORD OF CONVERSATION

Point of Contact:

    Karl Krouse

Telephone: (708) 505-1919
FAX: (708) 505-1936
Date: 2 May, 1996

Name and Organization:

    Calgon

SUBJECT: Carbon Metal Adsorption Limitations

The metals of concern from Calgon's regeneration view point are :

Cadmium	These metals may approach the upper limit
Chromium	for Carbon acceptance for regeneration
Cobalt	and the spent carbon would require disposal instead.

Iron may be a problem and scaling may be a problem.

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Phone Conversation Record

Person Called:	**Karl Krause**	Filename:
Company:	**Calgon**	c:\jan\boarhead\roc\gacroc1.doc
Phone :	(708)505-1919	
Fax:	(708)505-	

Person Calling:	Janelle Mavis
Date:	24 Apr 96

Subject: Liquid GAC Units, Installation, O&M and Carbon Changeout **(Using Less Stringent Pennsylvania Water Quality Effluent Requirements)**

(a) Virgin Carbon cost ranges from $0.70 to $3.00 per pound. Reactivated Carbon cost ranges from $0.45 to $0.65 per pound.

(b) Calgon has a reactivation facility in Pittsburg, PA approximately 300 miles from Boarhead Farms, PA.

(c) Maximum spent carbon that can be transported on the roads is 20,000 pounds. The total weight of the carbon and water is 40,000 lbs plus the 18 wheeler truck weight of xx lbs.

    Civil Considerations:
        18 wheeler Truck Weight = 60,000 lbs
        Turn Around radius Required for 18 wheeler
        20 ft hose comes with the truck for slurrying carbon in/out

Model 8:   **10,000 lbs carbon**
        Ht: 108 " = 9'   Dia. = 8 '   Full Operating Wt: 98,000 lbs
        Capital Cost = $87,000 with carbon vs $76,000 for Model 6 with 6,000 lbs carbon
        Headloss through unit at 60 gpm = 0.9 ft

Estimated Changeouts per Year:
        Carbon Usage Rate (CUR) = 85 lbs per 24 hr day (43 lbs / 12 hr day)
        one month = 1250 lbs
        232 days = 10,000 lbs or approx. 400 days before 80 % breakthrough for the 2nd unit
        Use 1 changeouts per year for estimation of cost.

        Transportation cost = $2.00 per mile with 600 miles round trip = $1,200 per trip
        Carbon Costs = 20,000 lbs * $0.45/lb = $9,000 for carbon
        <u>Total Cost for changeout = $11,000</u>

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Total Cost for Carbon per year = $9,000

Changeout Requirements

    1. Could provide carbon exchange ports (clean & spect carbon) at the building wall. These ports would have to be piped to the units or could provide a flexible hose to be left on site for this purpose.

    2. Fill from top and drain from bottom.

    3. Flood bed with water and apply pressure to top of vessel. Provide hose bib and air pressure port at the GAC location.

    4. Total gallons needed for transporting carbon in/out of truck = 5,000 gallons at about 20 to 100 gpm. The larger the flowrate will only shorten the slurry transfer time.

    5. Tee off downstream of the feed pumps to provide a connection for the use of raw water in the slurrying in and out of carbon. Raw water can be used but treated effluent is ideal.

    6. The GAC units come separately and are fastened to the housekeeping pads. The isolation piping for the lead/lag and slurying in/out of the carbon somes on a skid.

    7. Add notes to the drawings or specs but do not show the process flow piping, too cumbersome.

References:
(1) R.A. Dobbs and J.M. Cohen, Carbon Adsorption Isotherms for Toxic Organics, EPA 600/8-80-023, 1980.
(2) Harry Freeman, Hazardous Handbook of Hazardous Waste Treatment and Disposal 1989.
(3) Remove Organics by Activated Carbon Adsorption, Mark Stenzel, Calgon Corp., April 1993, Chemcial Engineering Progress Mag.

Plant Flowrate gpm = 50 gpm

(A) **The Fruendlich Isotherm Equation** $x/m = KC^{1/n}$

where:
x = amount of solute adsorbed (mg)
m = mass of adsorbent (g)
C = concentration of adsorbent remainig in solution after adsorption is complete (mg/L)
K, n = constants reference Dobbs and Cohen

(B) **Carbon Usage Rate (CUR)** $CUR = (Ci - Ce) / (x/m(Ce))$
where:

Ci = Influent Concentration (mg/L)
Ce = Effluent Requirements (mg/L)
$x/m(Ce)$ = amount of adsorbed per mass of adsorbent (mg/g)
CUR = Carbon Usage Rate

(C) **Conversions**
454 grams = 1 pound   1440 minutes = 1 day
3.785 liters = 1 gallon

example = 50 gal/min * 3.785 liter/gal * CUR gram/liter * 1 lb/454 grams * 1440 min/day = X lbs/d

Contaminant	K ** (mg/g)	1/n **	Influent Ci (mg/L)	Effluent Ce (mg/L)	x/m(Ce) (mg/g)	Ci - Ce (mg/L)	Carbon Usage Rate (g/L)	CUR (lbs/d)
1,1-Dichloroethene	4.9	0.54	0.03	0.007	0.336	0.023	0.07	41
cis-1,2-Dichloroethene	12	0.59	0.25	0.07	2.499	0.18	0.07	43
1,1,1-Trichloroethane	2.5	0.34	1	0.2	1.446	0.8	0.55	332
Trichloroethene TCE	28	0.5	6	0.005	1.980	5.995	3.03	1,818
Benzene	36	0.48	1	0.005	2.830	0.995	0.35	211
Tetrahloroethene PCE	50.8	0.6	0.15	0.005	2.115	0.145	0.07	41
1,1-Dichloroethane	1.8	0.53	0.05	0.004	0.046	0.049	1.06	636

** K & 1/n Constants from EPA 600/8-80-023 and Calgon Column Tests

*** Treating 100% of the influent concentrations.

CUR per 12 hr day =   909 lbs per 12 hr day

AR309240

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APPENDIX

PADER MEMO'S

EFFLUENT REQUIREMENTS

A-54
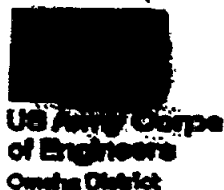
**U.S. ARMY
CORPS OF ENGINEERS
FORT CROOK AREA**

US Army Corps
of Engineers
Omaha District
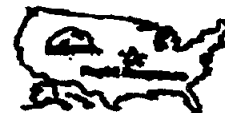
Phone: (402) 293-2300
Fax: (402) 291-3177

FORT CROOK AREA OFFICE
P.O. BOX 13087 BLDG 637
OFFUTT AFB, NEBRASKA 68113

Please deliver the following pages to:

NAME	PHONE	FAX ( )
Janelle Mavis		221-3842
COMPANY/OFFICE		
CEMRO - ED - DK		

FROM		
Wally Shaheen		
DATE	# PAGES NO. COVER	
5/6/96	5	

June 31, 1994 PADER memo which
addressed surface discharge limits for
purge water and which EPA has
directed us to use for this action.
We will issue a memo back to EPA
to place a discharge number where
the criteria calls for "98% removal" and
to indicate all constituents we plan to
monitor.

AR309242

A-55

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
841 CHESTNUT BUILDING
PHILADELPHIA, PENNSYLVANIA 19107

FAX TRANSMITTAL

PAGE 1 OF ~~8~~ 4

DATE: 4/29/96

PROJECT: Boarhead

PLEASE DELIVER AT ONCE TO:

NAME: ~~Wally Schaheen~~ Jim Boran

FIRM NAME: Corps | USACE

PHONE: (402) 221-7748

FAX NUMBER: -7848

FROM: Jim Harper / Wally Shaheen

PHONE: (215) 597-6906

FAX NUMBER:

COMMENT/NOTE: Harry gave me these limits - he feels they are too stringent ~~but~~ he said the analytical data shows we could easily meet these ~~B~~except for acetone - I've got support data

Jim

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5/2/96

Jim Beran

This is a copy of the "new" discharge criteria I received from Jim Harper. It doesn't look any different to me than the discharge table we had before which referenced a PADER 1994 memo which we didn't have before. This might be the 1994 PADER memo, but I don't have my files with me.

Notice the 98% removal of some constituents. That criteria makes it worse (very bad) if the level of that particular constituent is low !! I don't like this list.

Could you compare it to the previous list we had before and to our proposed list and determine where we should go from here. I'll try to get w/you on Monday. I'm travelling on Friday and probably won't be able to call you. What I'm saying is we may have to push for using our proposed list.

Let's talk . . . .

A-57
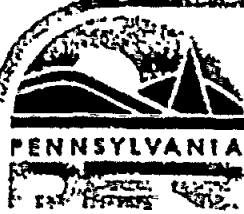
PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
Lee Park, Suite 6010
555 North Lane
Conshohocken, PA 19428-2251
June 21, 1994

Southeast Regional Office   (610) 832-6131
                                                        FAX: (610) 832-6259

Mr. Harry Harbold
Project Manager
EPA Region III
841 Chestnut Building
Philadelphia, PA 19107-4431

                        Re: Boarhead Farms NPL Site
                              WQ: General IW Correspondence
                              Bridgeton Township, Bucks County

Dear Mr. Harbold:

    This is in reference to your March 28, 1994, letter requesting approval for
a temporary discharge of treated groundwater, generated during a 48-hour pump
test, at each of the ten new monitoring wells at the referenced site.

    The groundwater will be treated and discharged at a rate of 28,000 -
72,000 gpd directly over the surface, in the vicinity of each well. Approval to
discharge during 48-hour pump test is granted subject to the following
conditions:

1. When sanitary sewers are adjacent to the site, permission to discharge
    to the sanitary sewers has been denied by the sanitary sewer system
    owner.

2. Influent and effluent samples shall be collected and analyzed for each
    well. At least one representative sample shall be taken at start-up of
    the pump test, at the middle of the pump test duration and one at
    the end of the pump test.

3. The following pollutants must be analyzed and all analysis reports
    must be submitted within 28 days after completion of the test to us
    and the Bucks County Health Department. The treated discharge shall
    not exceed the following effluent limits expressed as mg/l:

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AR309245

Mr. Harry Harbold   - 2 -   June 21, 1994

Parameter	Effluent Limit	Parameter	Effluent Level
Antimony	0.006	1,2-Dichlorethane	0.005
Beryllium	0.004	1,1-Dichloroethene	0.007
Cadmium	0.005	Ethylbenzene	0.7
Chromium, Total	0.1	Methylene Chloride	98% of influent removal
Copper	1.0	Tetrachloroethene	0.005
Lead	Monitor	Toluene	1.0
Nickel	0.1	1,1,1-Trichloroethane	0.20
Thorium	Monitor	Trichloroethylene	0.005
Zinc	5	Vinyl Chloride	0.002
Manganese	0.05	Cis-1,2-Dichloreothene	0.07
Vanadium	0.1	Acetone	98% of influent removal
2,4-Dichlorophenol	98% of influent removal	Naphthalene	98% of influent removal
Benzene	0.005		
Carbontetrachloride	0.005		
1,1-Dichloroethane	98% of influent removal		

4ppm influent — Manganese
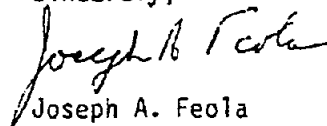
4. No erosion of the ground surface, banks or stream bed shall be induced by
    this discharge; appropriate erosion and sedimentation controls shall be
    installed.

5. Our Operations Section and Bucks County Health Department shall be notified
    24 hours prior to the discharge.

This approval does not include authorization to discharge during the proposed six
month to one year long term pumping test. For a long term pumping test or system
startup a request must be submitted in the format of a NPDES permit application (copy
enclosed). All monitoring data including the results of the 48 hour pump test must
be submitted.

If you have any questions, please contact Sohan Garg of our staff.

Sincerely,

Joseph A. Feola
Water Management
Program Manager

cc: Mr. Ewald
    Bridgeton Township
    Bucks County Health Department
    Mr. Newbold
    Mr. O'Neil
    Re 30 (SMC)131.1

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AR309246

Treatment Requirements for Volatile Organics Boarhead Farms Upper Black Eddy, PA		
Compound	Expected Influent Quality (mg/L) (A)	Effluent Requirements (mg/L) (B)
Acetone	.01	3.7
Chloromethane	.004	monitor
EthylBenzene	.004	0.7
Methylene Chloride	.02	0.005
1,1-DiChloroEthene	.03	0.007
1,1-DiChloroEthane	.05	0.810
cis-1,2-DiChloroEthene	.25	0.07
1,1,1 TriChloroEthane	1	0.2
TriChloroEthylene TCE	6	0.005
Benzene	1	0.005
1,1,2-TriChloroEthane	0.002	monitor
TetraChlorEthene (PCE)	0.15	0.005
Toluene	0.8	1
Vinyl Chloride	0.001	0.002
Xylene	0.01	monitor
Carbon Disulfide	.0.002	monitor
2,4-DiChloroPhenol	ND	0.11
CarbonTetraChloride	ND	0.005
Naphthalene	ND	1.5
1,2-DiChlorethane	ND	0.005

(A) Estimate based on weighted average of water quality for extraction wells analyzed during pump tests. No other volatiles or semi-volatiles were detected.
(B) As determined by the Pennsylvania Department of Environmental Resources in .June 21, 1994 Memo to Hary Harbold.
(ND) Not detected in any of the wells to be pumped during the interim action.

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Treatment Requirements for Metals Boarhead Farms Upper Black Eddy, PA		
Compound (Total Metals)	Expected Influent Quality (mg/L) (A)	Effluent Requirements mg/L (B)
Aluminum	5.321	monitor
Antimony	0.002	0.006
Arsenic	0.001	monitor
Barium	0.4	monitor
Beryllium	0.001	0.004
Cadmium	0.014	0.005
Calcium	101.8	monitor
Total Chromium	0.1	0.1
Cobalt	0.06	monitor
Copper	0.02	1.0
Iron	37	monitor
Lead	0.003	monitor
Magnesium	44	monitor
Manganese	4	0.05
Mercury	0.001	monitor
Nickel	0.12	0.1
Potassium	2	monitor
Silver	0.001	monitor
Sodium	13	monitor
Thallium	0.001	monitor
Thorium	ND	monitor
Vanadium	0.008	0.1
Zinc	0.03	5
Cyanide	0.011	monitor
Chloride	18	monitor
TDS	690	monitor
Sulfate	400	monitor

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Treatment Requirements for Metals Boarhead Farms Upper Black Eddy, PA		
Compound (Total Metals)	Expected Influent Quality (mg/L) (A)	Effluent Requirements mg/L (B)
pH	6.0 - 9.0	6.0 - 9.0
Alkalinity	25	monitor

(A) Estimate based on weighted average of water quality for extraction wells analyzed during pump tests. No other volatiles or semi-volatiles were detected.

(B) As determined by the Pennsylvania Department of Environmental Resources in June 21, 1994 Memo to Hary Harbold.

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APPENDIX

ALTERNATIVES FOR TREATMENT TECHNOLOGIES

Alternatives for Treatment Technologies

for

Contaminated Groundwater

at

Boarhead Farms, PA

Prepared by:

U.S. Army Corps of Engineers
Omaha District
May, 1996

I Introduction.

This summary report is intended to describe different treatment options and provide a cost comparison of the different alternatives at Boarhead Farms, Pennsylvania Groundwater Treatment Facility. The groundwater is contaminated with VOC's, hydrocarbons, and metals. The influent concentrations and flowrate into the plant may vary considerably. This report will include a description of the different alternatives, applicability, limitations, operation and maintenance (O&M) concerns, capital cost plus one year of (O&M) cost, and the recommend alternative treatment train.

The information discussed below is a compilation of conversations with vendors and textbook references. See the attached records of conversations.

II Description of Alternatives for VOC treatment.

1. Description of Process

a. Air stripping with Off-gas Treatment. Air Stripping is a process in which volatile organics are partitioned from groundwater by greatly increasing the surface area of the contaminated water exposed to air. VOC and hydrocarbon contaminated groundwater may be treated by air stripping with a shallow tray aerator. The off-gas will be treated with vapor phase granular activated carbon (GAC). Liquid phase GAC will be provided as a polishing step.

b. Liquid Phase Granular Activated Carbon (GAC) Treatment: Liquid Phase (GAC) treatment is a process in which groundwater is pumped through a series of vessels containing activated carbon where dissolved contaminants adsorb onto the carbon. VOC and hydrocarbon contaminated groundwater may be treated by liquid phase carbon alone.

2. Applicability

a. Air Stripping with Off-gas Treatment. Air stripping, vapor phase GAC, and liquid phase GAC are proven technologies for removing VOC's and hydrocarbons (TCE, PCE, DCE, BTEX). Vapor phase carbon will treat the off-gas from the air stripping unit to meet the state of Pennsylvania air quality standards. Air stripping with off-gas treatment and liquid GAC, as a polishing step, will be capable of treating a varying range of influent concentrations and will ensure that the effluent requirements are met. Moderate modifications to the number of trays in the stripper or the number of units may be needed if the influent concentrations increase dramatically.

b. Liquid Phase GAC Treatment: Liquid phase carbon is a proven technology for the treatment of VOC's and hydrocarbons. The liquid phase GAC will be capable of treating a varying range of influent concentrations. Moderate modifications to the number of units may be needed if the influent concentrations increase dramatically.

3. Limitations: Factors that may limit the effectiveness of the processes include but not limited to:

a. Air Stripping with Off-gas Treatment.

   1) Iron content - It is recommended to pre-treat for iron removal if the influent concentration is above 5 mg/l. Iron bacteria fouling may foul the stripper and carbon units. Iron pre-treatment may be performed with lime softening, chemical precipitation, aeration etc.. Waste streams generated from pre-treatment of iron and scaling compounds may potentially require additional treatment before disposal.

   2). Scaling Compounds - Recommend reducing the calcium and magnesium and non-carbonate hardness ion concentrations to prevent the air stripper from scaling.

b. Liquid Phase GAC Treatment

   1) Iron content - It is recommended to pre-treat for iron removal if the influent concentration is above 5 mg/l. Iron bacteria fouling may foul the stripper and carbon units. Iron pre-treatment may be performed with lime softening, chemical precipitation, aeration etc.. Waste streams generated from pre-treated of iron and scaling compounds may potentially require additional treatment before disposal.

   2) Scaling Compounds - Recommend reducing the calcium and magnesium and non-carbonate hardness ion concentrations to prevent the GAC from scaling.

   3) Metals Loading - The levels of cadmium, chromium, & cobalt may over time adsorb onto the carbon, if not removed first, and overload the carbon with metals. The metals can not be removed from the carbon during the regeneration process. This metal overloading may create a disposal issue for the spent carbon. Pre-treatment for metals removal include chemical precipitation and/or ion exchange.

   4) Carbon Usage Rate (CUR) - A high CUR is estimated, then on-site regeneration would be recommended. On-site regeneration using steam or heat add another process to maintain.

4. Operation & Maintenance Concerns:

   a. Air Stripping with Off-gas Treatment. If no pre-treatment for iron and scaling compounds is performed then periodic acid washing of the tray aerator may be required. The liquid phase GAC unit also may potentially foul or scale up before the carbon has been exhausted. This would dictate early changeout of the carbon unit. Spent carbon generated during the liquid phase GAC process would be regenerated off-site.

   b. Liquid Phase GAC Treatment. The liquid phase GAC unit may potentially foul or scale up before the carbon has been exhausted. Since the estimated changeout rate is high, the carbon may be exhausted due to the contaminants rather than fouling or scaling. Changeout of the carbon requires a O&M person on-site. Spent carbon generated during the liquid phase GAC process would be regenerated off-site.

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5. Cost Comparisons:

Alternative 1 : Tray Aerator with Vapor Phase GAC and Liquid GAC

Vapor Phase Capital Cost =	$18,800
Vapor Phase Refill Cost (4 * 1800) =	$ 7,200
Vapor Phase Transportation Cost (4*1200)=	$ 4,800
Liquid Phase GAC (1 unit) Cost =	$9,400
Tray Aerator Capital Cost=	$20,000
Electrical Cost =	$ 5,800
TOTAL COST PER YEAR =	**$66,000 for alternative 1**

Notes:

(1) Vapor Phase: 1800 lbs carbon divided by 20 lbs/d = 90 days life of vessel   Say 4 changeouts per year

(2) Liquid Phase: 1 unit will last over one-year

Alternative 2: Liquid Carbon Only

Liquid Phase Capital Cost (2*$87,000) =	$174,000
Liquid Phase Carbon Change out (12*9000)=	$108,000
Liquid Phase Transportation (12 * 1200)=	$144,000
Liquid Phase Support Equipment =	$50,000 +
TOTAL COST LIQUID GAC =	**$476,000 + for alternative 2**

Notes:

(1) Support Equipment Required: 9,000 gal Effluent Storage tank used for changeout purposes, backwash pumps 100 gpm, access road and turn around requirements

(2) 10,000 lbs / 750 lbs/12hr d = 13 days   Changeout both units once a month or 12 times

III Description of Metals Removal

1. Description of Process

a. **Chemical Precipitation:** Chemical precipitation is a process by which a soluble substance is converted to an insoluble form. Chemical precipitation units will include pH adjustment, chemical addition, flocculation/coagulation compartments, clarifier, filtration, sludge handling equipment with sludge dewatering.

b. **Ion Exchange:** Ion exchange is a chemical sorption process that removes ions from the aqueous phase by the sorption of cations or anions onto the resin. Ion exchange resins can be described simply as synthetic organic materials, inorganic and natural polymeric materials, which are capable of entering into chemical reactions with the constituents in the waste stream. Resins can be regenerated for reuse after their capacity has been exhausted.

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2. Applicability

a. Chemical Precipitation: Chemical precipitation has wide applicability and is recognized as a proven process for the removal of toxic metals from aqueous wastestreams. This waste includes metals such as, cadmium, chromium, copper, lead, mercury etc. This process may be adapted to varying influent concentrations. Chemical precipitation provides pre-treatment for metals prior to VOC and hydrocarbon treatment processes.

b. Ion Exchange: Ion exchange is applicable for dissolved metals removal. Ion selective resin either as "cation" or "anion" resin is available. Currently cadmium is the only constituent that must be removed from the groundwater to meet the effluent requirements for metals. There are ion selective resins available to remove only copper, zinc, or nickel, however there are no ion selective resins available to remove strictly cadmium. A special sodium chelating resin is available to remove cadmium, however it will also remove several other cations such as nickel, lead, potentially iron, cobalt etc. VOC removal is recommended before the ion exchange process because the VOC's will destroy the resin's effectiveness in adsorbing the metals.

3. Limitations

a. Chemical Precipitation: When the waste stream contains a variety of metals that must be removed, more process steps can easily be added. Example if chromium reduction is required to reduce Hexavalent chromium, more toxic form, to trivalent chromium - insoluble form. Also, the optimization of one metal may prevent the removal of another. Proper pH adjustment will be required for the treatment process. Additional polymers may be required to achieve the solids removal.

b. Ion Exchange: Ion exchange rarely represents an option for the ultimate disposal of hazardous wastes since the process generates chemical wastes which must almost invariably be further treated or disposed of. The contaminants can be removed from the resin by chemical regeneration with acids or alkalis.

1) Pre-Treatment for VOCs - Ion-exchange resins are destroyed by some organic substances. Several ion-exchange vendors highly recommended removal of the VOC's prior to the ion exchange process. Some vendors would not regenerate the resin if VOC removal was not performed prior to the ion exchange unit.

2) Currently the total chromium influent concentration of 0.1 mg/L equals the effluent requirements for total chromium of 0.1 mg/L. If the influent concentration of chromium increase and treatment is required a separate "anion" resin ion exchange unit would be required. The anion resin would also adsorb the chloride and sulfates present in high concentrations in the influent stream. The high concentrations of non-toxic metals would exhaust the ion resin rapidly. The estimated number of 30 cubic foot ion exchange resin changeouts per year would be greater than 700. Because of the cost for changing out the resin (700 * $3450 / changeout = $2.41 million per year) was uneconomical compared to chemical precipitation.

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3) Ion Exchange is not feasible if the suspended solids (SS) content is greater than 10 ppm. The SS may cause resin blinding. Filtration may be required to reduce the SS content.

3) Waste Stream Disposal

a. Ion Exchange The estimated regeneration wastestream is 5 % of approximately 2100 gallons per day. This water would require further treatment through chemical precipitation, evaporation, or disposal off-site to an appropriate treatment and disposal facility.

b. Chemical Precipitation The sludge produced by chemical precipitation must be dewatered before disposal. The sludge can be dewatered with a filter press. The filter cake generated must be sampled and disposed as a hazardous or non-hazardous waste. The filtrate will be discharged ahead of the chemical precipitation plant. If the sludge fails TCLP it will be classified as hazardous and will be disposed of appropriately.

4. Operation & Maintenance Concerns:

a. Chemical precipitation: The O&M required to operate this process includes: mixing up the chemicals, ordering the chemicals, emptying the press, sampling the sludge cake and disposal coordination of sludge cake - estimated as weekly, monitoring the process as required etc.

b. Ion Exchange: The O&M required to operate this process includes: ion resin changeout estimated as weekly, coordination of resin changeout, monitoring the process as required etc. No on-site regeneration of resin was evaluated because of the additional treatment processes required.

5. Cost Comparison

Alternative 1 Chemical Precipitation

Chemical Precipitation Packaged
Unit Capital Cost = $140,000
Filter Press = $ 18,000
Sludge Disposal = $ 7,500
O&M Operator Cost = $ 41,600
(O&M) Chemical Cost per year = $ 10,000
              Total Cost =   **$217,100 for alternative 1**

Notes:
(1) This process does not require any pre-treatment unit.
(2) Vendor - Great Lakes Chemical Precipitation Packaged unit includes: pH adjustment, chemical feed pumps and ORP monitors, flocculation compartment, mixers, clarifier, filters, final pH adjustment , sludge handling equipment .
(3) JD Anderson quote for filter press = $18,000

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(4) Estimated gallons treated per year = 55 gpm * 60 min/hr * 12 hr / day * 365 days / yr
14.5 million gallons

     (5) Estimated chemical costs = $0.30 to $0.70 / 1000 gallons treated

        14.5 million gallons / 1000 gal treated = 14,500 * $0.3 = $4400
        14.5 million gallons / 1000 gal treated = 14,500 * $0.7 = $10,150

     (6) Estimated Sludge Removal costs = $0.50 / 1000 gallons treated

        14.5 million gallons / 1000 gal treated = 14,500 * $0.5 = $7,250

     (7) Operator Cost = 16 hours per week at $50 per hour * 52 weeks = $41,600

Alternative 2 Ion Exchange

Ion Exchange Rental Costs =	$7,500
O&M Operator Cost =	$ 20,800
Resin Off-site Regeneration Costs =	$134,200
Resin Changeout Transportation =	$100,000 depending upon vendor location
Total Cost =	**$262,500 for alternative 2**

Notes:

     (1) The Ion Exchange Process required pretreatment of the VOC's. The VOC's destroy the resin sorption capacity.

     (2) Sodium Special Chelating Resin Only Estimated 52 changeouts per year.

     (3) No on-site regeneration, therefore no on-site treatment of regeneration wastestream. Ion exchange canisters to be transported off-site for regeneration.

     (4) Operator Cost = 8 hours per week at $50 per hour * 52 weeks = $20,800

IV Treatment Process Options.

Option 1 Chemical Precipitation with sludge handling followed by air stripping with off-gas treatment and liquid GAC as a polishing unit.

Chemical Treatment Costs (including 16 hrs/wk O&M) =	$217,100
VOC Treatment Costs =	$ 66,000
TOTAL PROCESS EQUIPMENT & O&M COSTS	
for ONE YEAR =	**$283,100**

O&M Operator Cost (16 hrs per week) =	$41,600
(O&M) Chemical Precipitation Chemical Cost per year =	$10,000
Sludge Disposal =	$ 7,500
Vapor Phase Carbon Refill Cost (4 * 1800) =	$ 7,200
Vapor Phase Transportation Cost (4*1200)=	$ 4,800
Liquid GAC (1 unit) Cost =	$ 9,400
Electrical Cost =	$ 5,800
O&M YEAR TWO AND FORWARD =	**$86,300**

Option 2 Pretreatment for iron and scaling compounds with sludge handling followed by liquid carbon followed by ion exchange.

Pre-treatment for iron/scaling Costs =	$ 50,000
PreTreatment Chemical Costs per year =	$ 5,000
Sludge Disposal =	$ 7,500
VOC Treatment Costs =	$476,000
Ion Exchange with O&M 8 hrs/wk Operator Costs =	$262,500
TOTAL PROCESS EQUIPMENT & O&M COSTS for ONE YEAR =	$796,000

O&M Operator Cost (16 hrs per week) =	$ 41,600
PreTreatment Chemical Costs per year =	$ 5,000
Sludge Disposal =	$ 7,500
Liquid Carbon Change out (12*9000)=	$108,000
Liquid Carbon Transportation (12 * 1200)=	$144,000
O&M YEAR TWO AND FORWARD =	$310,100

Option 3 Pretreatment for iron and scaling compounds with sludge handling followed by air stripping with off-gas treatment followed by ion exchange.

Pre-treatment for iron/scaling Costs =	$ 50,000
PreTreatment Chemical Costs per year =	$ 5,000
Sludge Disposal =	$ 7,500
VOC Treatment Costs =	$ 66,000
Ion Exchange with O&M 8 hrs/wk Operator Costs =	$262,500
TOTAL PROCESS EQUIPMENT & O&M COSTS for ONE YEAR =	$391,000

PreTreatment Chemical Costs per year =	$ 5,000
Sludge Disposal =	$ 7,500
Vapor Phase Carbon Refill Cost (4 * 1800) =	$ 7,200
Vapor Phase Transportation Cost (4*1200)=	$ 4,800
Liquid GAC (1 unit) Cost =	$ 9,400
Electrical Cost =	$ 5,800
Ion Exchange Rental Costs =	$7,500
O&M Operator Cost (8 hrs per week) =	$ 20,800
Resin Off-site Regeneration Costs =	$134,200
O&M YEAR TWO AND FORWARD =	$202,200

NOTES: The above costs do not include the wells, collection trench, building, utility connections, access road, piping and trenching, piping inside of building, mechanical equipment, electrical equipment, heating and ventilation operating costs per year.

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V Recommended Option

Optional

Chemical Precipitation with sludge handling followed by air stripping with off-gas treatment and liquid GAC as a polishing unit.

    a) the treatment train provides flexibility in modifying the system, chemical precipitation is known to be an effective treatment process, with high performance in treating varying influent concentrations and flowrates.

    b) the treatment train has an estimated 16 hours per week O&M requirement. O&M labor costs is cheaper than ion exchange regeneration costs. One ion exchange changeout costs approximately $4500 which corresponds to 90 operator hours at $50 per hour.

    c) the treatment train is most economical based on estimated costs from discussions with vendors

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VI References:

(1) Remediation Technologies Screening Matrix and Reference Guide, EPA/542/B-94/013

(2) Water Treatment Principle and Design, James M. Montgomery, 1985

(3) Standard Handbook of Hazardous Waste Treatment and Disposal, Harry M. Freeman, 1989

(4) Calgon, record of conversations

(5) US Filter, record of conversations

(6) Great Lakes Environmental Inc., record of conversations

(7) Raines & Associates, record of conversations

(8) J.D. Anderson, record of conversations

(9) A Better Earth, record of conversations

(10) Culligan, record of conversation

(11) Lancy Environmental, record of conversation

APPENDIX

LITERATURE REVIEW

SULFEX™ PROCESS

A PROVEN TECHNOLOGY FOR THE REMOVAL OF HEAVY METALS

BY

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SULFEX™ PROCESS

A PROVEN TECHNOLOGY FOR THE REMOVAL OF HEAVY METALS

INTRODUCTION:

During 1968-1969, mercury contamination of natural waters retarded growth of certain species of fish. The residual carryover of mercury in the fish for human consumption became a major concern. As a result, industries discharging wastewaters containing heavy metals, (copper, zinc, nickel, cadmium, etc.) to natural waterways came under close scrutiny by the EPA. As the public pressure grew, the EPA began monitoring discharges and started developing stringent guidelines to be followed by electroplaters and other industrial polluters. Some of these limits set by the EPA were difficult to achieve due to limitations of the then available treatment method, commonly known as hydroxide precipitation process. In this process, lime or caustic is added to the metal bearing wastewater and metals are precipitated, flocculated, settled and removed as metal hydroxides. Although a well designed and operated system can provide excellent results, there are two basic deficiencies:[7]

1. The metal hydroxides are amphoteric in nature and an operating pH ideally suited for efficient removal of one metal is unfavorable for the good removal of another.

2. In the presence of chelating agents such as EDTA, metal hydroxide precipitation is incomplete.

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Further, with ever increasing stringent limits (at ppb levels) for discharge of metal bearing solutions, hydroxide precipitation alone cannot meet the required effluent permit limits.

Realizing the need for an efficient removal of metals in the presence of complexing agents Permutit concentrated its efforts in developing such a process, with two major objectives:

1. The process must be workable over a wide spectrum of waste compositions.

2. It should not require any specialized equipment or skills foreign to the end user; i.e., we should use as far as possible, available water treatment equipment to fulfill objective "1".

The development of the Sulfex™ Process meets both the above objectives and has been in commercial use for several years. This precipitation technique involves an exchange of ions between the sulfide of an added heavy metal and the legand of the pollutant ion(s). Hence, the name "SULFEX™". This process is covered by two (2) U.S. Patents. The following presentation details process chemistry and its application with available treatment equipment, modes of application and operating experience.

SULFEX™ PROCESS CHEMISTRY:

Precipitation of heavy metals both as hydroxides and as sulfides has been well documented in the literature. (References 1, 4, 5, 6, 7.) The EPA[1] report provides an excellent summary of chemistry, operational aspects of both hydroxide, soluble sulfide and insoluble sulfide processes for heavy metal precipitation. However, the following section, Sulfex™ Process Chemistry is provided for completeness of this presentation.

Theoretical Solubilities of Heavy Metals:

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Table I shows the solubilities of many of the heavy metals of interest, both as hydroxides and as sulfides. In general, the metal sulfides tend to be at least 4 or 5 magnitudes less soluble than the metal hydroxides except chromium. (A solid form of chromium sulfide does not occur in aqueous solution). It is this property of the heavy metal sulfides that makes sulfide precipitation the classic method for separation and analysis of heavy metals in water. This property also makes sulfide precipitation an extremely effective way to remove heavy metals from water.

Figure I shows the theoretical or calculated solubilities of various examples of these heavy metals as a function of pH value. The solubilities are shown in terms of the concentration of dissolved metal (in mg/l). There are three (3) important solubility differences between the hydroxides and sulfides illustrated by these relationships.

1. The solubilities for each of the given metals are all lower for the sulfides than for the hydroxides.

2. The metal sulfides tend to have very low solubilities even at pH values of 7.0 or less, whereas, the hydroxide solubilities are considerably high (greater than 1.0 mg/l) at neutral pH values for many heavy metals.

3. Some of the metal hydroxides tend to re-dissolve upon increasing the pH value above a certain critical value for each metal. This is called "amphoterism". On the other hand, the solubilities of the sulfides tend to keep decreasing as the pH value increases.

In summary, at any pH value, the precipitation of a mixture of several heavy metals by addition of dissolved sulfide will, theoretically, produce a lower concentration of dissolved metals than hydroxide precipitation, and the soluble concentration of trivalent chromium (not

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shown in Figure I) will be the same, at any pH value, whether sulfide or hydroxide precipitation is used, since only the hydroxide will form.

Sulfide Precipitation of Heavy Metals:

In order to precipitate any of the heavy metals as sulfides, the sulfide source added to the solution of the metal must be more soluble than the metal sulfide to be precipitated. As the added sulfide dissolves, the dissociated sulfide ion then reacts readily with the heavy metal that has lower sulfide solubility. When equilibrium is reached, the metal of lower solubility will be precipitated and the one of higher solubility will remain dissolved. For example, Na_2S (sodium sulfide), when added to water, readily dissolves or dissociates into sodium and sulfide ions:

$$Na_2S + H_2O = 2\,Na + S = +\,H_2O$$
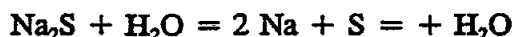
and the free sulfide ion ($S=$) reacts with more water to form free H_2S gas.

$$2\,Na + S^= + H_2O = 2\,OH + H_2S\,(Gas) + 2\,Na$$

If an equivalent amount of a heavy metal is present, the sulfide ion will preferentially precipitate with it, rather than forming H_2S, and Na^+ will be left in the solution;

$$2Na_2S + H_2O + Cu^{++} = CuS + 2\,Na + H_2O$$
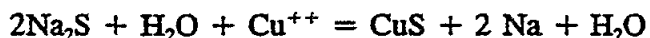
However, if the amount of sodium sulfide added is in excess of the required amount to precipitate all the heavy metal, the excess sulfide will form H_2S gas which can be liberated from the solution to a greater or lesser degree depending on the pH value of the solution;

$$2Na_2S + H_2O + Cu^{++} = CuS + 4\,Na^+ + S^= + H_2O \qquad S^= + H_2O = H_2S\,(Gas)$$
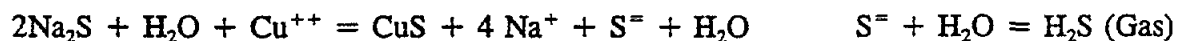
It is this possibility of H_2S production that has kept sulfide precipitation an undesirable treatment method. It is nearly impossible to consistently add the exact amount of sulfide required. If sulfide is underfed, the metal is not completely removed and if overfed, H_2S is

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liberated. In addition, operating experience indicates that the metal sulfide precipitated with the use of soluble sulfide source tend to form extremely fine colloidal particles (pin floc) and are difficult to agglomerate and settle. In spite of these problems, sulfide precipitation has been used when it was desired to obtain very low residual concentrations of metals.

Sulfex™ is a new type of sulfide precipitation process, developed so that the excess sulfide required can be added to a heavy metal solution without releasing H_2S. This is accomplished by adding another metal sulfide whose solubility is too low to release H_2S, but whose solubility is high enough to provide the necessary sulfide ions to react with the heavy metals. This process is patented and is covered by two (2) U.S. Patents. They are:

1.   U. S. Patent 3,740,331 - "Method for Precipitation of Heavy Metal Sulfides" -

Inventors: Dr. John R. Anderson and Charles O. Weiss. June 19, 1973.

This patent relates to preparation of ferrous sulfide by the addition of ferrous sulfate and sodium sulfide solutions to precipitate heavy metals as sulfide.[8]

2.   U.S. Patent 4,102,784 - "Colloid Free Precipitation of Heavy Metal Sulfides" -

Inventor: Richard M. Schlauch. July 25, 1978.

This patent relates to the specific method of preparation of FeS slurry for the application in the removal of heavy metal pollutant to cause large particle size precipitate for easy settling and subsequent removal.[9]

Starting with a soluble sulfide, such as NaHS, this is reacted with an equivalent or excess amount of ferrous ion (Fe^{++}) so that there can be no excess sulfide relative to the ferrous ion. Therefore, the only ionic sulfide that will be present is due to the solubility of FeS.

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Since FeS is rather insoluble, only 2×10^{-2} parts per billion of free sulfide is present in a natural aqueous solution. This concentration is too low to produce an odor of H_2S, but it is high enough to react with the heavy metals that are less soluble when combined with sulfide. This is true no matter how much excess FeS is present, provided the pH is controlled to the alkaline side.

Table II lists the concentrations of soluble sulfides existing in equilibrium with the solid sulfide phases of the heavy metals of interest. Note that the concentration of free (dissolved ionic) sulfide, at equilibrium, is many orders of magnitude greater for FeS than it is for the other heavy metals. This difference establishes the driving force that causes the more insoluble metals to precipitate as sulfides. Therefore, there is migration of sulfide from the FeS to the more insoluble metal. When equilibrium is reached, the Fe^{++} ion will have been stripped of its sulfide, allowing soluble Fe^{++} ion to be free in the solution.

$$CuSO_4 + H_2O = Cu^{++} + SO_4^{=} + H_2O$$

$$FeS_{(s)} + H_2O = Fe^{++} + S^{=} + H_2O$$

$$Cu^{++} + SO_4^{=} + Fe^{=} + S^{=} + H_2O = Fe^{++} + CuS_{(s)} + SO_4^{=} + H_2O$$
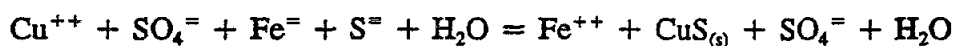
To prevent the above from occurring, the pH of the water is maintained in the range of 8.5 to 9.0 causing the iron to precipitate as ferrous hydroxide. Iron is relatively insoluble under these conditions, normally less than .5 milligrams per liter, such concentrations of iron are considered non-toxic and very acceptable in an ecological system.

$$Fe^{++} + SO_4^{=} + Ca(OH)_2 + H_2O = Fe(OH)_2S + Ca^{++} + SO_4^{=} + H_2O$$
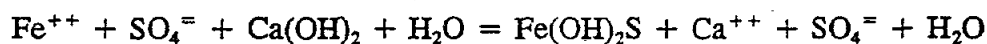
The addition of lime (or caustic soda) to elevate the pH and precipitate the excess iron also improves the removal of copper and other heavy metal sulfides because they too are less soluble

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at the higher pH values. The one exception to this rule is chromium ion, commonly found in wastewaters. However, since chromium has a low hydroxide solubility (less than 0.05 mg/l) in the pH range between 8 and 9, it can be removed simultaneously with the rest by the lime addition in the same way Fe^{++} is removed.

Theoretical Requirements of FeS:

Each mg/l of heavy metal has its own theoretical requirement of FeS, and can be calculated assuming heavy metals are dissolved in pure solutions. Based on these values and the actual concentrations of metals analyzed in wastewater, theoretical requirement of FeS is calculated for each application. However, from practical standpoints there are two (2) important problems.

First, reaction kinetics can be limited by "mass transfer" and when we are trying to react heavy metal ions that are present in parts per million or parts per billion, we cannot expect each ion to travel long distances to locate and react with a particular equivalent sulfide ion. Therefore, we must provide an excess of sulfide ions relative to the heavy metal ions that we wish to precipitate.

The other problem is that many wastewaters contain an assortment of acidic and basic complexing agents that have previously reacted with the heavy metals to form soluble molecular complexes that are relatively stable. These complexes do not reduce the total concentration of heavy metal, but they do reduce the effective ionic concentration, thus making it more difficult to complete reaction between a heavy metal ion and a sulfide ion. Since the bond between sulfide and most heavy metals is stronger than the bond between complexing agents and heavy metal, sulfide precipitation of these metals prevails. On the other hand, the bond between complexing agents and the metal is often as strong or stronger than the metal hydroxide bond,

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preventing hydroxide precipitation. This makes it necessary to increase the dosage of FeS to a greater extent above the theoretical requirement, and in some cases to allow more time so that the desired reaction can be completed.

Because it is often not known what complexing agents or sequestering agents are present in a given wastewater, it becomes important to conduct tests to determine how much excess FeS is required.

Note here that the input of FeS, relative to the input of heavy metals, does not require a rigorous ratio control, inasmuch as it is practical to maintain a reserve supply of unreacted FeS in the system. In some respects, this can be thought of as a one way ion exchange resin which is kept in the system with the wastewater running through; if there is a momentary high input of heavy metal, the excess iron sulfide solids will be instantly ready to react with metal species and precipitate as metal sulfide.

FeS Reactions and Requirements as a Reducing Agent for Cr^{+6}:

An important advantage of the Sulfex™ Process is its ability to remove hexavalent chromium in one step as opposed to the typical two-step process used with hydroxide precipitation. We assume that the Sulfex™ reaction proceeds as follows:

$$CrO_4^= + 4\ H_2O + FeS_{(s)} = S_{(s)} + Fe(OH)_{3(s)} + Cr(OH)_{3(s)} + 2\ OH$$

Please note chromium is removed as hydroxide precipitate.

With respect to FeS requirement laboratory studies combined with operating experience indicate that Cr^{+6} reduction and subsequent precipitation as trivalent chrome hydroxide require 1.0 to 1.5 times theoretical requirement.

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Limitations:

From the foregoing discussions of process chemistry, we do realize the following limitations:

1. With every mg/l of heavy metal precipitation as sulfide, there is a corresponding precipitation of ferrous hydroxide, resulting in increased volume of precipitate. This does not occur with hydroxide precipitation of metal. Therefore, in designing a Sulfex™ Process consideration is always given for two precipitator systems, one operating as hydroxide precipitator and the other as Sulfex™ polisher. This reduces significantly FeS reagent usage and the sludge volume produced.

2. Since we are trying to remove exclusively very low concentrations of heavy metals from wastewaters containing many other dissolved solids and complexing agents, we require excess amounts of FeS to react with these heavy metals, to produce an effluent quality contain close to or below detection limits. However, the use of upflow sludge blanket principle in the precipitator tends to minimize the FeS usage due to its intimate contact with the incoming wastewater.

SULFEX™ PROCESS EQUIPMENT:

As mentioned earlier, one of the requirements of the development of the Sulfex™ Process was to utilize available process equipment familiar to the water treatment industry. Permutit's in depth experience in water treatment clarification, settling and filtration combined with available equipment design helped greatly in commercial application of the Sulfex™ Process. In the precipitation of heavy metals with ferrous sulfide, the chemical reactions take place rather quickly. Relatively fine, near colloidal particles form and these precipitates are further

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conditioned to insure proper settling in the clarifier. The following will briefly discuss mechanical and hydraulic separation of the reacted materials in the clarification and filtration steps of the process.

Figure 2 is the cross section of our Hull Type Precipitator, commonly used for higher flow rate plants.

For example, in the precipitator, the influent raw liquor and chemicals are introduced and sometimes pre-mixed in a flash mixer prior to entering the inlet flume. It then flows downward into the mixing and reaction zone of the precipitator. The counter-current action of the horizontal agitator pulls a certain amount of the precipitate back into the mixing and reaction zone to provide intimate contact between the old and newly precipitated materials. By varying the speed of the agitator, the concentration in the mixing/reaction zone can be varied from three to nine times that of the amount of material being newly precipitated. The Permutit precipitator also operates with a sludge blanket. The sludge blanket provides additional contact with the precipitated materials and at the same time provides for upflow filtration of the liquid through the blanket. The heavier materials are allowed to settle into the sludge concentrator zone for removal. To insure complete utilization of the chemicals employed, the sludge blowoff header is flushed back, prior to sludge blowoff. This pushes the precipitated materials back up into the sludge blanket and insures removal of only the heaviest materials.

The precipitator's sludge blanket also contains the excess iron/sulfide required in the Sulfex™ Process, which, is required to precipitate certain heavy metals. The iron sulfide is utilized only as needed and does not require the precise control that would be necessary with other types of clarification systems that do not utilize the sludge blanket principle of operation.

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In spite of the use of upflow sludge blanket precipitator and the use of polymers, the precipitator effluent contains minute quantities of precipitates. The precipitator effluent is further filtered in the Sulfex™ filters to remove any remaining suspended particles. The filtered effluent is normally discharged to the sewer or natural waterways.

The sludge blown off from the precipitator is collected and de-watered in the filter press. The de-watered sludge (cake) is then hauled to the approved waste dumps.

Modes of Application:

In the past 13 years of its commercial application, the Sulfex™ Process has been used in three (3) modes, namely, primary, polishing and batch system. The primary treatment system consists of basically a single clarifier utilizing FeS feed system, whereas the secondary treatment system consists of two (2) clarifiers one operating as hydroxide precipitator (addition of lime or caustic) and the second clarifier operating as polisher with a sulfide feed system. The batch system basically treats wastewater in small batches using FeS feed system.

Although each waste treatment system is specially designed to meet individual requirements, most of the systems normally contain four (4) basic components along with controls. They are:

1.   Equalization tank and pH adjustment: Since most wastewaters containing heavy

        metals fluctuate considerably in their compositions due to dumps of concentrated

        metal bearing baths and accidental spills, waste streams are generally collected

        in equalization tanks and pH is adjusted by the addition of lime and/or caustic.

        In extreme cases two stage neutralization is considered for precise pH

        maintenance. Equalization tank and pH adjustment is common to most systems.

2. Chemical feed system and precipitator: Chemical feed systems usually consist of chemical make-up tanks (polymer and FeS) and associated pumps to deliver chemicals. The clarifier is the upflow sludge blanket type with its flushback and sludge blow-off systems. In cases where influent metal concentrations are very high and reduction in sludge volume is required, two (2) clarifiers in series are used. The first clarifier is used as a hydroxide precipitator with the addition of lime or caustic for substantial removal of heavy metals as hydroxides and the second clarifier is used with FeS feed as a polishing clarifier to remove only the residual metals left over from the hydroxide step. This mode of polishing Sulfex™ application reduces substantially the chemical requirement as well as the sludge volume produced.

3. Sulfex™ filter: A Sulfex™ filter is commonly used to remove minute quantities of suspended particles, (heavy metal sulfide precipitates along with some unreacted FeS) present in the clarifier effluent. The unreacted FeS coats the filter media and facilitates further removal of residual dissolved metals from the precipitator effluent.

4. Filter press: A plate and frame filter press is normally used to de-water the sludge removed from the precipitator. The de-watered sludge (cake) is hauled to the State approved land fill.

OPERATING EXPERIENCE:

As mentioned earlier, the Sulfex™ Process has been in commercial use for the past 13 years. To date we have sixteen (16) successfully operating systems with flows ranging from 50 GPM

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to 200 GPM in the states of Wisconsin, Minnesota, Tennessee, Indiana, New Jersey, Washington State, Michigan, etc. These commercial installations represent metal finishing, automotive, semi-conductor industries. In all cases, the effluent quality produced has met the local, state and federal discharge limits.

Most wastewater treatment systems are designed on the basis of wastewater analysis provided by the end user and/or consulting engineers. In spite of considerable effort during initial design in waste stream isolation and characterization to derive the influent waste composition under the actual operating conditions, the influent composition changes not only due to accidental spills and dumps, but also due to process modifications to improve economics and product quality. The Sulfex™ Process at several of these installations has been able to adopt and cope with the major changes in the process stream and still produce the desired effluent quality.

Occasionally we receive calls from our customers detailing how the effluent quality has deteriorated, only to find out an accidental spill had occurred on a midnight shift 5 or 6 days before. During this time, the precipitator was able to accommodate the excess metal load without any adjustments in the FeS feed, utilizing the unreacted excess FeS in the sludge blanket to produce the desired effluent quality.

One of our customers has a two precipitator system without a Sulfex™ filter. This installation has been in operation for three (3) years and has consistently produced desired effluent quality. The operators at this installation are conscientious and maintain excellent records through which they have gained considerable experience in maintaining the plant.

Another of our customers is in the business of collecting metal bearing inorganic waste solutions from small platers of automotive industries and treating the waste prior to disposal to

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the public sewer system. Waste treatment is their business! Recent stringent quality required by regulatory agencies governing electroplaters effluents were difficult to meet consistently with the existing treatment system. Since incorporating a Sulfex™ polishing system a year ago, they have been not only meeting the effluent quality, but have also been able to accommodate wider fluctuations of metal concentration in the influent wastewater. According to the customer, Sulfex™ has not only proven to be effective in the presence of chelating agents, but also has made the operation profitable.

In the last 2 years, advances in analytical techniques and instrumentation combined with toxicity tests as requirements have upgraded the quality of wastewater to be discharged for the public streams. As a result, regional EPA centers are requiring more stringent quality in the effluent and are seeking metal concentrations in ppb levels.

During a recent study of Sulfex™ Process by one of our customers, it was revealed that the heavy metal concentrations in the effluent samples determined by the ICP method (Inductive Coupled Plasma) showed higher values for certain metals compared to the values obtained by Graphite Furnace Technique both utilizing atomic absorption spectrophotometer. The metal concentration values reported have been the lowest reported so far. Results have been encouraging. Due to improvements in analytical techniques, we are able to guarantee a much more stringent quality than we did before. Also in the same study, limited toxicity tests were conducted with Sulfex™ effluent and results have been encouraging.

SUMMARY:

The Sulfex™ Process is a technically viable process in achieving extremely low level concentrations of metals in the treatment of metal bearing wastewaters prior to their disposal.

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This process removes chelated metals from wastewater and simultaneously reduces hexavalent chromium in one step at a single pH. Operating experience with various types of commercial installations indicates that with the Sulfex™ Process, whether in primary, polishing or batch application, meets most discharge limits. It is safe and very easy to operate. From the practical standpoint, the system design with Permutit upflow · sludge blanket precipitator permits accommodation of wider fluctuations in the influent metal concentrations without affecting the effluent quality. Recent advances in analytical techniques in measuring very low levels of metals (ppb range) and the successful limited toxicity test data undoubtedly are proving the potential of the Sulfex™ Process in meeting future stringent discharge limits. Operating case histories showing years of trouble free performance are available on request.

ACKNOWLEDGMENTS:

The authors would like to express their deep appreciation to Mr. Richard M. Schlauch of Stablex Corporation for his valuable comments. Also our sincere thanks to Mrs. Sheila Manks for typing the manuscript.

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Theoretical solubilities of Metal Hydroxides and Sulfides as a function of pH

Figure I.

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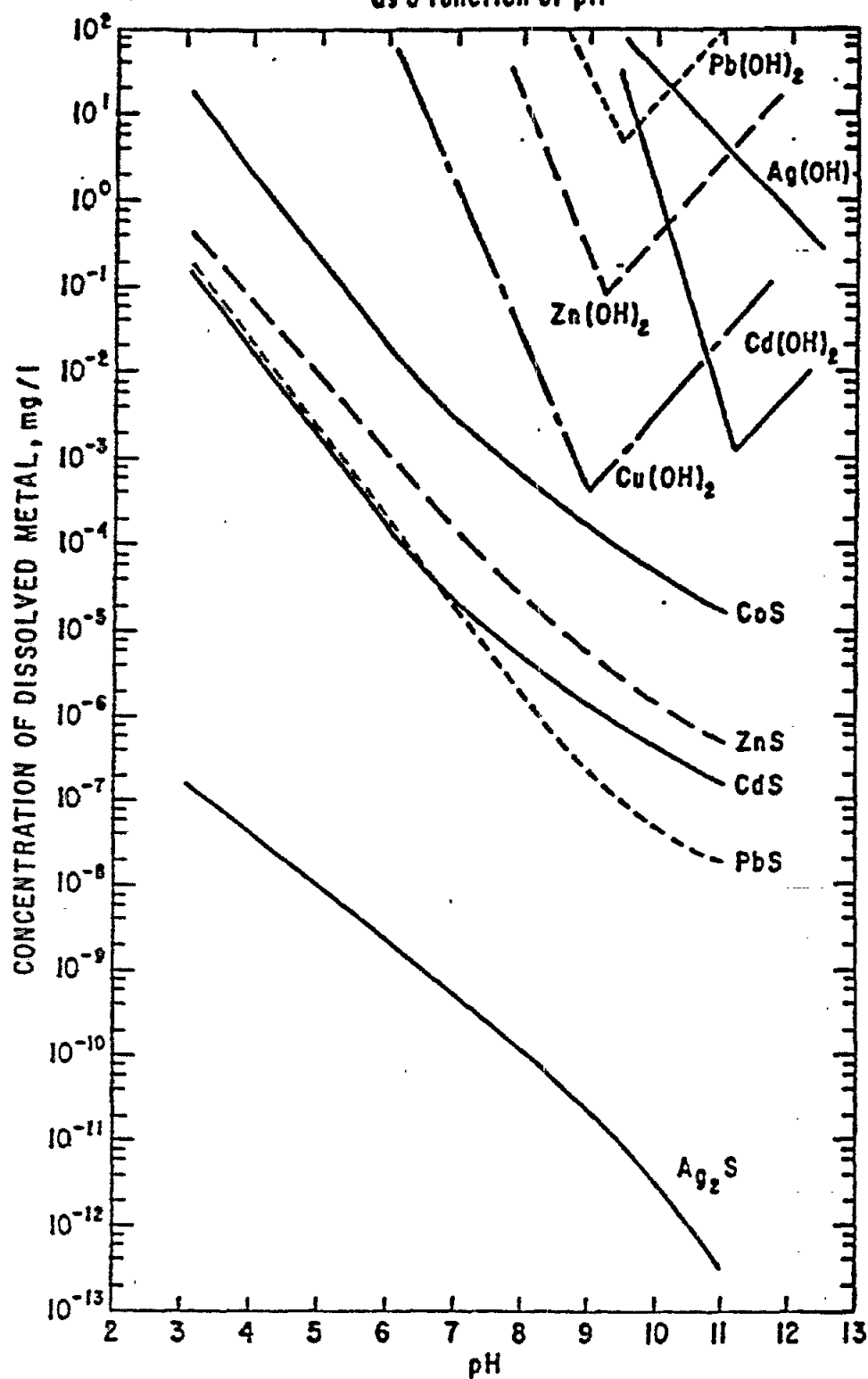
FIG. 2
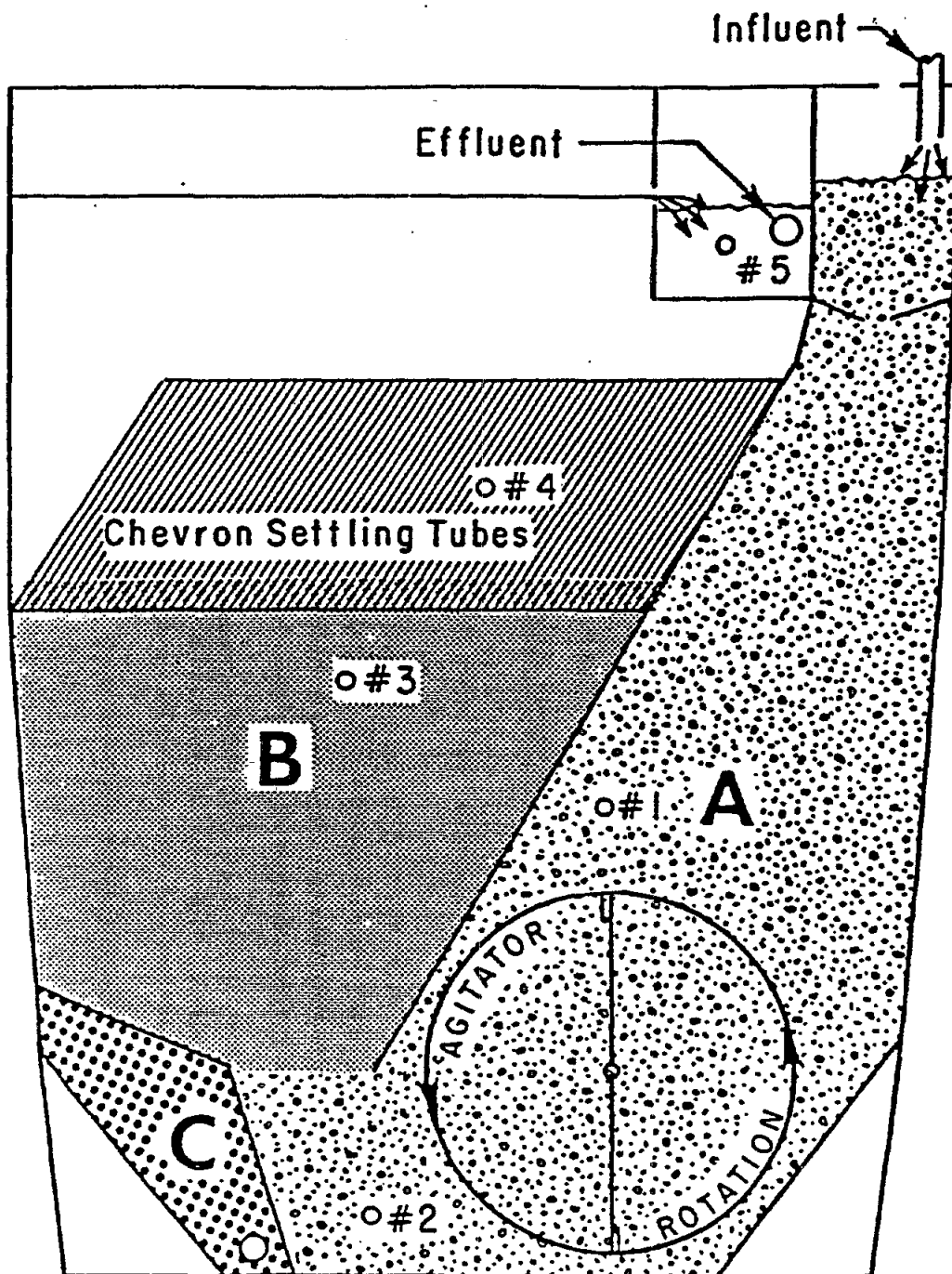
Figure 2. Cross-section of Precipitator mixing and settling zones.

TABLE I

THEORETICAL SOLUBILITIES OF HYDROXIDES AND SULFIDES OF HEAVY METALS IN PURE WATER

Metal	Solubility of Metal Ion (mg/l)	
	As Hydroxide	As Sulfide
Cadmium (Cd^{+++})	2.3×10^{-5}	6.7×10^{-10}
Chromium (Cr^{++})	$*8.4 \times 10^{-4}$	No Precip.
Cobalt (Co^{++})	$*2.2 \times 10^{-1}$	1.0×10^{-8}
Copper (Cu^{++})	$**2.2 \times 10^{-2}$	5.8×10^{-18}
Iron (Fe^{++})	8.9×10^{-1}	3.4×10^{-5}
Lead (Pb^{++})	$**2.1$	3.8×10^{-9}
Manganese (Mn^{++})	1.2	2.1×10^{-3}
Mercury (Hg^{++})	$*3.9 \times 10^{-4}$	9.0×10^{-20}
Nickel (Ni^{++})	$*6.9 \times 10^{-3}$	6.9×10^{-8}
Silver (Ag^{+})	13.3	7.4×10^{-12}
Tin (Sn^{++})	$**1.1 \times 10^{-4}$	$*3.8 \times 10^{-8}$
Zinc (Zn^{++})	1.1	2.3×10^{-7}

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Hogness and Johnson, Holt and Winston Co., 1954, pp. 360-362.

TABLE II

SOLUBILITY OF SULFIDES

Metal Sulfide	Ksp (18° to 25° C)	Sulfide Concentration Moles/L.
MnS	*1.4×10^{-15}	3.74×10^{-8}
FeS	*3.7×10^{-19}	6.1×10^{-10}
Zns	*1.2×10^{-23}	3.46×10^{-12}
NiS	*1.4×10^{-24}	1.18×10^{-12}
SnS	1.0×10^{-25}**	3.16×10^{-13}
CoS	*3.0×10^{-26}	1.73×10^{-13}
PbS	*3.4×10^{-28}	1.84×10^{-14}
CdS	*3.6×10^{-29}	6.0×10^{-15}
Ag_2S	*1.6×10^{-49}	3.4×10^{-17}
Bi_2S_3	1.0×10^{-97}	4.8×10^{-20}
CuS	*8.5×10^{-45}	9.2×10^{-23}
HgS	*2.0×10^{-49}	4.5×10^{-25}

References

*Handbook of Chemistry and Physics, 50th ed., R.C. Weast, ed.
The Chemical Rubber Co., 1969, p. B252.

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METAL FINISHING WASTEWATER TREATMENT UPGRADE
WITH AN INSOLUBLE SULFIDE PRECIPITATION PROCESS

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METAL FINISHING WASTEWATER TREATMENT UPGRADE WITH AN INSOLUBLE SULFIDE PRECIPITATION PROCESS

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INTRODUCTION

A large manufacturing complex owned by Texas Instruments Incorporated (TI) in Attleboro, Massachusetts is involved in the semiconductor packaging, metal finishing and metal forming operations for a diversified product line. These manufacturing operations generate numerous wastewater streams which require treatment prior to discharge.

Recently, the Attleboro facility received a new National Pollutant Discharge Elimination System (NPDES) Permit for surface water discharges. Because wastes are discharged to a stream with high quality, the new effluent limitations for the primary industrial waste stream, as dictated by the Amendments of 1977 to the Clean Water Act, are among the most stringent in the country. Additionally, the City of Attleboro received an NPDES Permit with similar limitations for its sewage treatment plant to which Texas Instruments direct a secondary industrial waste stream. New pretreatment standards for this stream reflect the Attleboro limits.

In order to comply with the new NPDES Permit limitations and the anticipated pretreatment standards for discharges to the city sanitary sewer, Texas Instruments retained United Engineers & Constructors for the design of the required industrial wastewater treatment system upgrade. The scope of the work for the project included a comprehensive source reduction study, pilot testing of state-of-the-art treatment technologies, and design implementation of these technologies and processes to polish the effluents prior to discharge. The project also required the design of modifications to the existing wastewater treatment systems and design of a new building addition to house the advanced treatment polishing systems.

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The advanced technologies which underwent comprehensive pilot testing included membrane microfiltration, chelating resin ion exchange, a soluble sulfide precipitation process, and an insoluble sulfide precipitation process (SULFEX™)[1]. Although each of the technologies showed encouraging results, the overall evaluation for this specific application favored selection of the insoluble sulfide precipitation which is the focus of this report.

BACKGROUND

DISCHARGE PERMIT REQUIREMENTS

In July 1977, Texas Instruments received a five-year National Pollutant Discharge Elimination System (NPDES) permit to discharge treated industrial wastewater to an on-site ten acre surface water body, Coopers Pond. TI had just completed the installation of a modern 600 gallon per minute waste treatment facility employing metal hydroxide precipitation. At the time, this system was considered to meet Best Available Technology (BAT) requirements, and it was based on such process chemistry criteria that the original permit limits were generated.

In 1982, however, when TI submitted a renewal application for its NPDES Permit, water quality criteria of the receiving stream in lieu of BAT was used by the U.S. Environmental Protection Agency to develop the new permit limits. This resulted in the imposition of very stringent effluent limitations in the new draft permit. Due to the limited dilution water available in TI's receiving stream, the proposed limits were deemed impossible to meet with any existing technology.

TI then faced a difficult decision on whether to attempt to seek relief from the non-attainable proposed limits through aquatic toxicity testing, or whether to re-direct the effluent to another receiving stream (i.e., the Publicly Owned Treatment Works). In the worst case, TI had to decide whether to shut-down its large Attleboro based manufacturing facility employing over 5,000 people and relocate to another area.

In the final analysis and after much deliberation, TI chose to maintain its Attleboro facility and enter into a long and relatively unexplored avenue of aquatic toxicity testing to raise its permit limits to achievable levels. It was realized early on, that, even if TI succeeded in raising the limits, the existing waste treatment facility would require substantial modifications.

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The Commonwealth of Massachusetts and the U.S. EPA are currently using site-specific water quality criteria in evaluating effects of direct discharges. These criteria are designed to evaluate effects of a discharge on representative, sensitive species plus indigenous populations and allow for establishing discharge limits which will protect aquatic environments. Data to support this program and establish acceptable in-stream limits are derived from a series of bioassays utilizing selected species exposed to effluent samples and site specific dilution water. When these studies indicate that a discharge has potential for adverse environmental impact, a toxicity reduction evaluation is conducted to determine the source of toxicity in the effluent and the means to reduce this source.

Early toxicity testing of TI's conventionally treated effluent determined that, in order to reduce toxicity, trace metals in the discharge would have to be reduced significantly. Through these tests, the U.S. EPA established in the draft permit the concentration of effluent trace metals which it believed would achieve the desired water quality in Coopers Pond.

To reach the goal of no toxic materials in toxic amounts, TI elected to evaluate advanced treatment technologies to determine if acceptable effluent quality could be attained. During this pilot testing program, a series of acute and chronic toxicity tests were conducted using treated effluent from the pilot units. The toxicity data generated during this period was evaluated and used by the U.S. EPA to establish somewhat less stringent limits in TI's final NPDES permit. Table I presents a comparison of the draft effluent limitations with those imposed by the final permit.

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TABLE I

NPDES PERMIT LIMITS (mg/l)

Parameter	Draft Permit Monthly Avg.	Draft Permit Daily Max.	Final Permit Monthly Avg.	Final Permit Daily Max.
Oil & Grease	15	15	15	15
TSS	20	30	20	30
Nickel	0.15	2.0	0.17	2.0
Iron	1.75	1.75	1.75	1.75
Aluminum	0.04	0.5	1.0	1.25
Copper	0.15	0.15	0.15	0.15
Zinc	0.5	0.75	0.4	0.75
Cadmium	0.025	0.025	0.025	0.025
Silver	0.008	0.035	0.007	0.05
Chromium (+3)	0.12	1.5	0.1	1.5
Chromium (+6)	0.01	0.02	0.09	0.09
Lead	0.01	0.15	0.031	0.15
Tin	0.01	0.08	0.02	0.08
Ammonia	1.6	4.1	1.7	4.1
Residual Chlorine	0.025	0.025	0.02	0.025
Selenium	0.1	0.45	0.1	0.45
Cyanide	0.015	0.04	0.13	0.185
Fluoride	2.6	2.6	9.0	9.1
Phosphorus	1.0	1.3	1.0	1.0
Palladium	1.05	1.1	1.05	1.1
Boron	0.015	0.02	2.0	2.0
Total Toxic Organics	-	2.13	-	2.13
NOAEL	-	60%	-	60%
NOCEL	-	-	-	Monitor Only

PILOT TESTING

In order to establish baseline toxicity, design and operating data for the advanced treatment processes required to meet TI's new permit limits, a comprehensive pilot testing program was developed. Selected state-of-the-art technologies which were tested included the following:

o   Insoluble (iron) sulfide precipitation process.

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o   Membrane microfiltration.

o   Chelating resin ion exchange.

o   Soluble (sodium) sulfide precipitation and filtration.

The testing program required several months of data collection, from June through October, 1985. As noted previously, effluent samples from each pilot unit were subjected to biotoxicity testing in addition to analyses for the constituents listed in the new discharge permit. This in-depth testing, data collection and data analyses eventually determined:

o   The feasibility of advanced treatment to produce an effluent meeting the new U.S. EPA discharge criteria.

o   Estimations of full-scale chemical consumption rates and chemical costs.

o   Operational and maintenance advantages and disadvantages of each process.

o   Process turndown capabilities and operational flexibility.

o   Full-scale design parameters.

For this specific project, the pilot testing favored the selection of the insoluble sulfide precipitation process for advanced treatment and polishing of TI's effluent from the existing hydroxide precipitation treatment system.

INSOLUBLE SULFIDE PRECIPITATION

<u>PROCESS CHEMISTRY DESCRIPTION</u>

The insoluble sulfide precipitation process is a wastewater treatment technology which has been proven effective in separating heavy metals from plating and metal finishing wastewaters. The process uses a freshly prepared ferrous sulfide (FeS) slurry as the source of the sulfide ions needed to precipitate the metals from the wastewater. The process operates on the principle that FeS will dissociate into ferrous ions and sulfide ions to the degree predicted by its solubility product. As sulfide ions are consumed by forming precipitates with metal ions in the wastewater, additional FeS will dissociate to maintain an equilibrium concentration. Ferrous ions dissociated from the FeS will precipitate as ferrous hydroxide at the alkaline pH (8 to 9 standard units) at which the process is operated. The sulfide precipitation process can produce an effluent having much lower dissolved metals

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than a hydroxide precipitation process because metal sulfides are much less soluble than metal hydroxides. Table II compares the solubilities of metal sulfides with hydroxides to illustrate this phenomena. Figure I shows the theoretical or calculated solubilities of various examples of these heavy metals as a function of pH value. The insoluble sulfide precipitation process removes only those metal ions which can form metal sulfides having lower solubility than the ferrous sulfide. For example, the process will not be effective for removal of manganese (Mn) because MnS is more soluble than FeS. The process will also not remove cyanides and other anions. Hexavalent chrome will be reduced to trivalent chrome and then removed by forming hydroxide precipitates according to the following reaction:

$$CrO_4^- + FeS + 4H_2O \longrightarrow Fe(OH)_3 + Cr(OH)_3 + S + 2\,OH^-$$
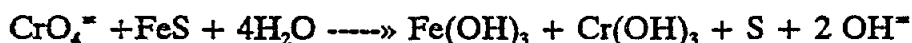
The process can be effective in removing dissolved metals from wastewaters containing certain common chelating agents and complex organics such as ammonium, succinates, gluconates, pyrophosphates, tartrates, Rochelle salts and EDTA. The degree of metal removal depends upon the specific chelating complex as well as the specific metal ion present in the wastewater. For example, the reaction with copper (Cu) ions in a solution containing EDTA can be predicted as follows:

$$Cu\,EDTA^{-2} + FeS \longrightarrow CuS + Fe\,EDTA^{-2}$$

The reaction will proceed to the right because CuS is less soluble than FeS and Fe $EDTA^{-2}$ is more stable than the Cu $EDTA^{-2}$ complex.

To control the excess iron in the system, the process is maintained at a pH in the range of 8.5 to 9.0 forming an iron hydroxide precipitate with the excess Fe ions. Within this pH range, there is no significant discharge of soluble sulfide or iron sulfide in the effluent to cause generation of hydrogen sulfide gas (H_2S). Routine operation of the process requires that excess ferrous sulfide be maintained in the reactor to accommodate any sudden increases in the concentrations of metal ions in the influent.

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TABLE II

THEORETICAL SOLUBILITIES OF HYDROXIDES AND SULFIDES
OF HEAVY METALS IN PURE WATER

Metal	Solubility of Metal Ion (mg/l)	
	As Hydroxide	As Sulfide
Cadmium (Cd^{++})	2.3 x 10^{-5}	6.7 x 10^{-10}
Chromium (Cr^{+++})	*8.4 x 10^{-4}	No Precip.
Cobalt (Co^{++})	**2.2 x 10^{-1}	1.0 x 10^{-8}
Copper (Cu^{++})	**2.2 x 10^{-2}	5.8 x 10^{-18}
Iron (Fe^{++})	8.9 x 10^{-1}	3.4 x 10^{-5}
Lead (Pb^{++})	**2.1	3.8 x 10^{-9}
Manganese (Mn^{++})	1.2	2.1 x 10^{-3}
Mercury (Hg^{++})	*3.9 x 10^{-4}	9.0 x 10^{-20}
Nickel (Ni^{++})	*6.9 x 10^{-3}	6.9 x 10^{-8}
Silver (Ag^{+})	13.3	7.4 x 10^{-12}
Tin (Sn^{++})	**1.1 x 10^{-4}	*3.8 x 10^{-8}
Zinc (Zn^{++})	1.1	2.3 x 10^{-7}

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THEORETICAL SOLUBILITIES OF METAL HYDROXIDES
AND SULFIDES AS A FUNCTION OF pH

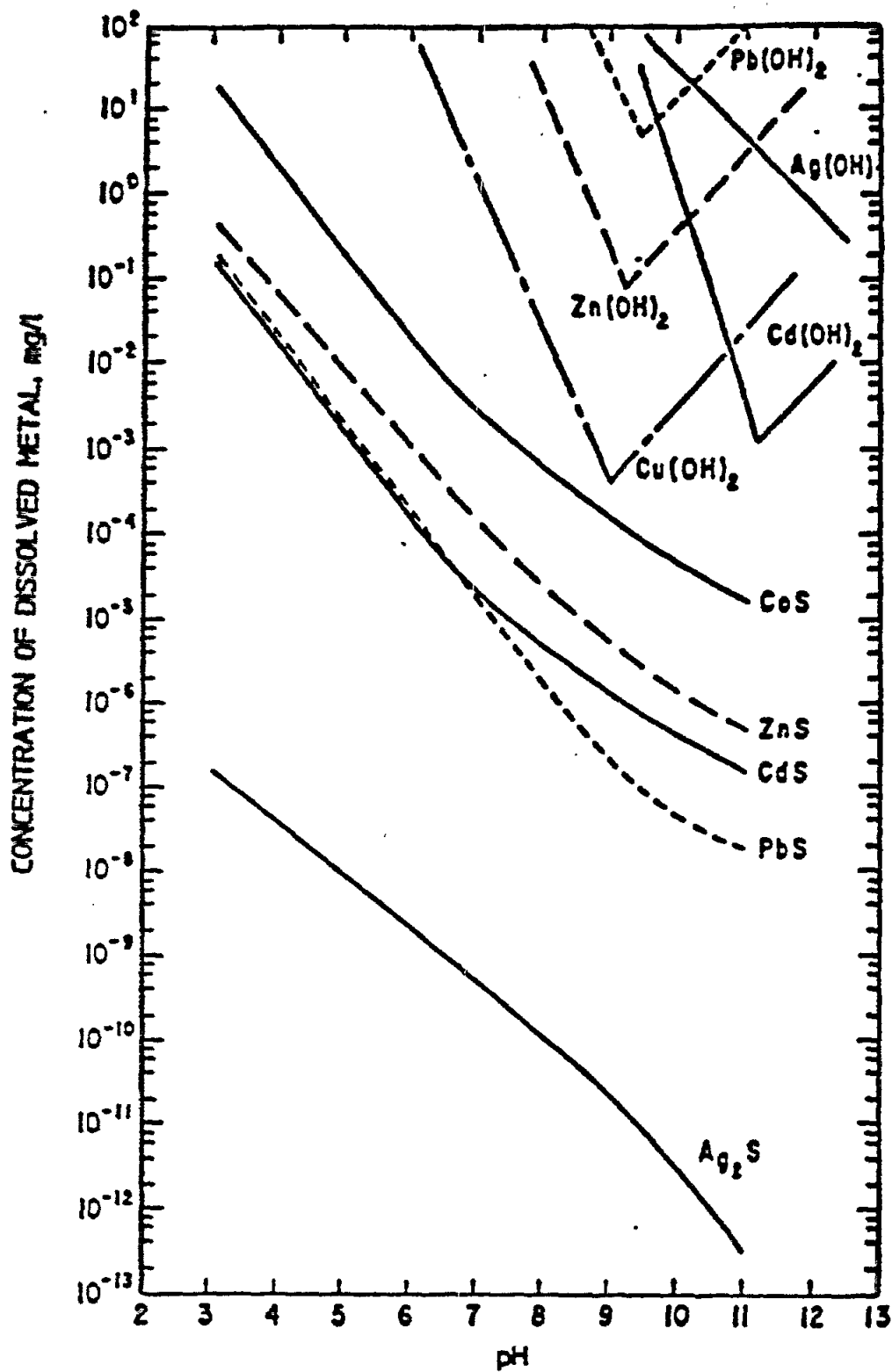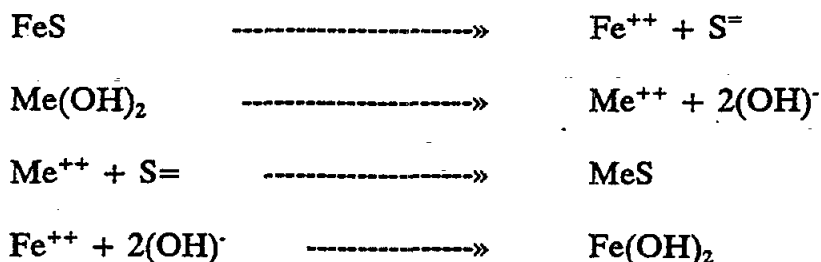FIGURE I

In the reactor, the FeS slurry dissolves to react with many other metal contaminants in the wastewater according to the following reactions (where Me = metal ion):

$$FeS \quad \text{-----------------}\!\!\!\gg \quad Fe^{++} + S^{=}$$

$$Me(OH)_2 \quad \text{-----------------}\!\!\!\gg \quad Me^{++} + 2(OH)^{-}$$

$$Me^{++} + S= \quad \text{-----------------}\!\!\!\gg \quad MeS$$

$$Fe^{++} + 2(OH)^{-} \quad \text{---------------}\!\!\!\gg \quad Fe(OH)_2$$

The overall chemistry of the process for metal (Me) removal may be illustrated by the following equations:

$$Me(OH)_2 + FeS \quad \text{------------------}\!\!\!\gg \quad Fe(OH)_2 + MeS$$

According to the above reactions, ferrous sulfide in the sludge blanket is gradually converted to ferrous hydroxide sludge. The increase of ferrous hydroxide in the sludge can impair the solubility of ferrous sulfide, thus limiting the available sulfide for metal precipitation. This occurs because $Fe(OH)_2$ is more soluble than FeS. High concentrations of ferrous ions in equilibrium with $Fe(OH)_2$ must be controlled through periodic blowdown of the mixed sludge in the reactor. Makeup of freshly prepared ferrous sulfide must be added to replenish that consumed by reaction conversion and sludge blowdown operations.

Economical operation of the insoluble sulfide precipitation process requires proper control of ferrous sulfide addition and sludge blowdown to minimize excess sulfide loss.

PILOT PLANT DESCRIPTION

The pilot plant for the process was delivered to the TI's Attleboro plant in mid-May, 1985. Following approximately two weeks of mechanical setup and process chemistry tuning, the pilot unit was set to operate on waste streams from TI's existing wastewater treatment facility.

The pilot plant consisted of three major components: a sludge blanket precipitator[2], a dual media filter, and a chemical feed system. The sludge blanket precipitator was separately skid-mounted with all other equipment mounted on a flat-bed trailer. Figure II presents a process flow schematic of the insoluble sulfide precipitation pilot plant.
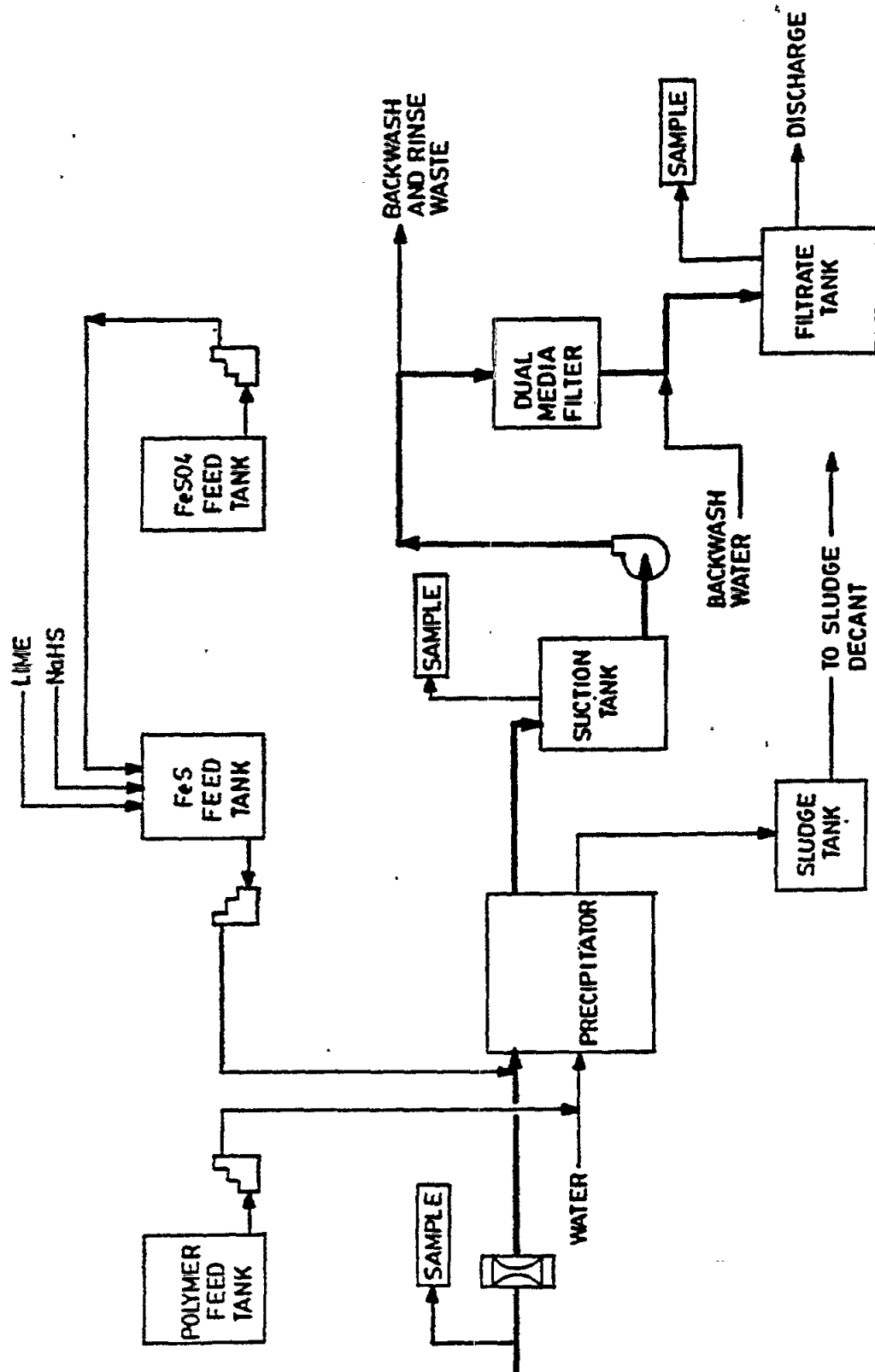
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FIGURE II

INSOLUBLE SULFIDE PRECIPITATION PROCESS
PILOT PLANT FLOW SCHEMATIC

Throughout the testing period, feed to the pilot unit (a portion of effluent from the existing hydroxide treatment plant) approximated 45 gallons per minute. Ferrous sulfide reagent and polymer were continuously fed into the precipitator influent. As shown in Figure III, the flow path of the wastewater is downward into the mixing and reactor zone of the precipitator. Near the bottom of the precipitator, a horizontal agitator pulls a certain amount of previously settled precipitate upward and back into the mixing and reaction zone to allow contact between old and newly precipitated materials. By varying the speed of the agitator, the concentration in the mixing and reaction zone can be varied from three to nine times that of the amount of material being newly precipitated. Further, the sludge blanket also provides additional contact with the precipitated material and at the same time, provides for upflow filtration of the liquid through the blanket. Heavier materials settle into the sludge concentrator zone prior to removal from the precipitator. To insure nearly complete utilization of the added chemical reagents, the sludge blowoff header requires flush back prior to sludge blowdown. This pushes precipitated material back up into the sludge blanket and ensures removal of only the heaviest material. During pilot testing, this operation proved very effective.

The pilot plant set-up directed precipitator overflow to a pump suction tank from which the wastewater was pumped at 15 gallons per minute through the dual media filter. Filter effluent and excess flow to the suction tank was discharged to the Attleboro plant's outfall.

During the test period, fresh batches of ferrous sulfide and polymer solutions sufficient for 24 hours operation were prepared daily. The entire system was operated 24 hours per day for a total of 30 working days. The system was not run during weekends or designated plant shutdowns. Filter backwash was carried out once a day.

SAMPLING AND DATA COLLECTION

Throughout testing, eight hour composite samples were collected from the filtered effluent. Correspondingly, influent samples to the precipitator were also collected. All samples were analyzed in the laboratory for metals limited by the discharge permit. In addition, four 24 hour composite samples were also collected, preserved and sent for independent analysis. Toxicity tests were also conducted on these 24 hour composite samples following EPA approved procedures.

Parameters which were also monitored included flow rate and pH of the influent and effluent samples for complete evaluation of the process. The ferrous sulfide feed was adjusted on the basis of total metal concentrations in the influent and, at times, were confirmed through jar tests.

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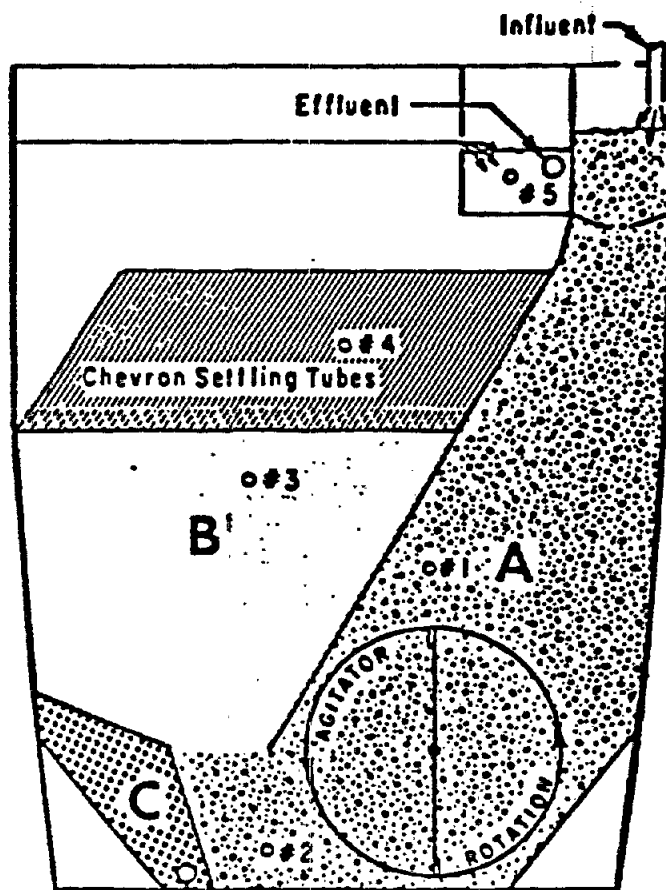
CROSS SECTION OF PRECIPITATOR

A. Mixing and Reaction Zone.

B. Settling Zone.

C. Concentrator Zone.

FIGURE III

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ANALYTICAL PROCEDURES

Analyses of all collected samples were performed in TI's laboratory where inductively coupled plasma spectrometry was primarily used. In addition, the 24 hour composite samples taken for toxicity testing were also analyzed using flame and graphite furnace atomic absorption spectrometry by Enviro-Systems Incorporated, TI's consultant for the toxicity testing program.

RESULTS AND CONCLUSIONS

PILOT TESTING PERFORMANCE

Influent Feed

The metal finishing process wastewaters at Texas Instruments were found to be highly variable in metal constituents during the course of the pilot testing program. Wide concentration variations were characteristic of samples collected from within the existing treatment system final clarifier and from the upstream final neutralization tank, both of which were a source of waste feed to the pilot unit during the different phases of testing. This variation in influent feed characteristics did not present a major problem to the insoluble sulfide precipitation process due primarily to the capabilities of the sludge blanket precipitator. Only slight adjustments in chemical feed rates were required based on periodic jar tests of the influent feed.

Metal Removal Efficiencies

Tables III and IV compare the quality of treated effluent, on the basis of an eight hour shift average, with respect to the draft and final U.S. EPA limits in the discharge permit. These results of the pilot testing program indicate that the insoluble sulfide precipitation process produces a quality effluent consistent in meeting the final EPA limits for zinc, cadmium, iron, copper, and chromium. Since the process also demonstrated relatively high removal efficiencies for boron, tin, silver, lead, nickel and aluminum, it is believed that full compliance with the discharge permit limits for these metals can be achieved by Texas Instruments through source reduction and in-plant controls in addition to advanced treatment by insoluble sulfide precipitation.

TABLE III

SUMMARY OF THE INSOLUBLE SULFIDE PILOT TEST PERFORMANCE
(SHIFT AVERAGE FOR THE PERIOD OF 6/7/85 TO 7/12/85)

	Zn	B	P	Cd	Fe	Sn	Ag	Cu	Pb	Ni	Al	Cr-T
Pilot Unit Feed	361	615	1,805	53	906	171	681	2,125	204	1,010	3,778	3,834
Precipitator Effluent	35	263	641	32	495	29	24	77	100	162	784	22
Final Filter Effluent	22	245	605	12	63	26	24	17	81	116	810	14
Draft EPA Limits	500	15	1,000	25	1,750	10	8	150	10	150	40	130
Final EPA Limits	400	2,000	1,000	25	1,750	20	7	150	31	170	1,000	190
Percent of Time Final Effluent Below Draft EPA Limits	100	0	90	100	100	50	(1)	100	50	75	0	100
Percent of Time Final Effluent Below Draft EPA Limits	100	100	93	100	100	73	(1)	100	(1)	77	80	100
Average % Removal by Precipitator	90	57	64	40	45	83	96	96	51	84	79	99
Overall Process % Removal	94	60	66	77	93	85	97	99	60	89	79	99

NOTE:

(1) Denotes values which could not be assessed because analytical instrumentation detection limits exceeded the EPA limits.

(2) Metal ion concentrations are expressed in micrograms per liter.

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TABLE IV

SUMMARY OF THE INSOLUBLE SULFIDE PILOT TEST PERFORMANCE
(SHIFT AVERAGE FOR THE PERIOD OF 8/26/85 TO 8/30/85)

	Zn	B	P	Cd	Fe	Sn	Ag	Pd	Cu	Pb	Ni	Al	Cr-T
Pilot Unit Feed	125	-	704	-	360	126	122	-	540	108	498	3,625	1,025
Precipitator Effluent	34	490	641	21	178	27	15	11	64	60	146	2,485	16
Final Filter Effluent	23	490	594	16	34	17	13	10	18	46	91	2,208	10
Draft EPA Limits	500	15	1,000	25	1,750	10	8	1,050	150	10	150	40	130
Final EPA Limits	400	2,000	1,000	25	1,750	20	7	1,050	150	31	170	1,000	190
Percent of Time Final Effluent Below Draft EPA Limits	100	0	100	90	100	55	(1)	100	100	(1)	90	0	100
Percent of Time Final Effluent Below Draft EPA Limits	100	100	100	90	100	73	(1)	100	100	(1)	90	18	100
Average % Removal by Precipitator	73	-	10	-	50	79	-	88	88	44	71	31	98
Overall Process % Removal	82	-	15	-	90	87	-	89	97	57	82	39	99

NOTE:

(1) Denotes values which could not be assessed because analytical instrumentation detection limits exceeded the EPA limits.

(2) Metal ion concentrations are expressed in micrograms per liter.

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pH

The values of influent waste pH were consistently well adjusted within the optimum range of 8 to 9 pH units prior to the wastewater entering the pilot unit. The process chemistry within the precipitator reduced the effluent pH by at least 0.5 pH units. A further reduction of 0.2 pH units was realized in the filtered effluent. Overall, the precipitated and filtered effluent was maintained at a slightly alkaline pH (approximately 8.0 pH units).

Chemical Consumption

A comparison of actual ferrous sulfide feeds with theoretical demands indicated that the process pilot unit was constantly fed with a surplus of the ferrous sulfide slurry throughout the testing period. By analyzing the metal constituents and concentrations in the feed wastewater and calculating the stoichiometric requirements of these metals, the theoretical demand for ferrous sulfide could be estimated. These calculated demands did not include the requirements for non-metallic species such as phosphorus and boron since their stoichiometric requirements are not clearly understood. However, based on these estimates, it was determined that an average of 3 to 5 times the theoretical ferrous sulfide requirement was supplied during the demonstration test runs.

The polyelectrolyte consumption also fluctuated. In some cases where high concentrations of suspended solids were present in the influent wastewater, increased polyelectrolyte usage was required. Results of this study indicated that approximately 0.5 to 1 mg/l of polyelectrolyte would be adequate for treatment of the existing system effluent.

TOXICITY TESTING RESULTS

One of the principal objectives of the pilot test program was to determine if TI's wastewater effluent, by undergoing advanced treatment, could be rendered non-toxic for discharge to the surface water outfall, Coopers Pond. As previously described, performance of the insoluble sulfide process was monitored for biological toxicity by scheduled sampling of the treated, filtered effluent. The results of toxicity testing of 24 hour composite samples are shown in Table V which also presents the concentrations of wastewater constituents.

Results of the acute bioassays clearly indicate that the insoluble sulfide precipitation process should produce an effluent which will consistently pass the toxicity tests required by the NPDES permit. Two of the acceptable chronic test results were encouraging because both samples were obtained during periods when the pilot unit was processing a relatively contaminated waste stream resulting from process bath dumps.

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Recognizing that the toxicity tests (utilizing the daphnid, Daphnia pulex, as the acute test organism) are subjective, it is difficult to establish reasons based on reduction of metal concentrations alone for a specific survival rate. However, the following explanations are offered as most probable:

o   With the insoluble sulfide precipitation process, only the heavy metals are removed by precipitation without any other significant change in the pH or in the chemical composition of the treated wastewater.

o   The process does not add any detrimental compounds to the wastewater while removing metals.

OPERATING COSTS

Operating costs for a 600 gallon per minute insoluble sulfide precipitation system as an advanced polishing treatment process at TI have been estimated to be $0.70 per 1,000 gallons of wastewater treated. Based upon data collected during pilot testing, this figure includes $0.15/1,000 gallons for chemical costs. TI's estimated costs for power ($0.10/1,000 gallons), sludge disposal ($0.25/1,000 gallons) and operating personnel ($0.20/1,000 gallons) were added to the chemical costs to derive the overall operating costs of the process.

CONCLUSIONS

The pilot testing, toxicity testing and operating cost evaluations convinced Texas Instruments that an upgrade of their existing wastewater treatment system should include insoluble sulfide precipitation as an advanced treatment process in order to meet the new NPDES Permit requirements. Final design of the wastewater treatment upgrade has been completed. The design has taken into account licensing considerations, system maintainability and reliability, and TI's commitment to total compliance with all local, state and federal environmental codes.

The advanced treatment plant will include a new 10,000 ft^2 building addition which will house two 300 gallon per minute equipment trains consisting of inclined plate clarifier/thickeners, sludge blanket precipitators, dual media filters and chemical feed systems. The treatment system will also include two new 250,000 gallon holding/equalization tanks to receive flow from the existing treatment plant before the wastewater is directed to the new advanced treatment system.

The new treatment plant is currently under construction. Startup is expected in mid-1987.

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TABLE V

SUMMARY OF RESULTS FROM REPRESENTATIVE ACUTE AND CHRONIC EFFLUENT BIOASSAYS: INSOLUBLE SULFIDE PRECIPITATION PROCESS

| | ------------------ TEST SERIES ------------------ | | | |
PARAMETER	6/20/85	6/26/85	7/3/85	7/12/85
Acute LC-50 (1)	100%	100%	100%	100%
Acute NOAEL (2)	100%	50%	100%	100%
Chronic NOAEL (3)	12.5%	20%	60%	80%
Hardness (mg/l)	76	48	51	66
Alkalinity (mg/l)	81	56	71	74
Ammonia (mg/l)	0.01	0.01	0.7	0.9
Residual Cl (mg/l)	0	0	0	0
pH (units)	7.66	7.80	7.94	7.70
Ag (mg/l)	0.005	0.025	0.0008	0.0005
Al (mg/l)	0.52	0.52	0.71	0.32
Cd (mg/l)	0.004	0.006	0.002	0.008
Cr (total) (mg/l)	0.0005	0.035	0.0005	0.0005
Cu (mg/l)	0.009	0.041	0.014	0.005
Fe (mg/l)	0.064	0.23	0.29	0.055
Ni (mg/l)	0.12	0.20	0.12	0.09
Pd (mg/l)	0.001	0.043	0.002	0.023
Se (mg/l)	0.01	0.01	0.01	0.01
Sn (mg/l)	0.01	0.045	0.01	0.01
Zn (mg/l)	0.008	0.028	0.004	0.005
Cr ($^{+6}$) (mg/l)	0.0005	0.035	0.0005	0.0005
CN (mg/l)	0.06	0.21	0.09	0.06
F (mg/l)	4.7	1.8	1.1	1.1
P (mg/l)	0.69	1.8	1.1	0.48
Pd (mg/l)	0.005	0.005	0.005	0.005
B (mg/l)	0.6	0.5	0.5	0.27

(1) LC-50 is the strength of the treated wastewater sample in which 50 percent of the test organisms survive 48 hours.

(2) NOAEL (Non-Observable Acute Effect Level) specifies the strength of the treated wastewater sample in which a major population of the test organism survives 48 hours.

(3) Chronic No Effect Level is the strength of the treated wastewater sample in which the normal life production cycle of juveniles of the major population of test organism is unaffected through 7 days of the bioassay testing.

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ACKNOWLEDGMENTS

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REFERENCES

1. SULFEX™ is a patented process of the Permutit Company.

2. The term "Precipitator" used throughout this report refers to a proprietary upflow, solids contact reactor-settles unit manufactured by the Permutit Company.

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SULFEX® Heavy Metals Waste Treatment Process
Meets EPA Effluent Standards ... Is Best Available Technology

Sulfex is a proprietary system developed by Permutit for removing heavy metals from process waste streams. Sulfex has particular application for the treatment of metal finishing and plating waste waters. Fifteen operating Sulfex plants are now in service; all meet rigid EPA effluent standards for discharge to surface waters or POTW.

Questions and answers about the Sulfex treatment process . . .

1. Why are the regulatory agencies concerned over the discharge of so called "heavy metals"?

Because heavy metals, which include zinc, copper, cadmium, nickel, chromium, mercury, lead, etc., have been found to have a delayed but very serious impact on the natural food chain going from algae through lower aquatic life to higher animals and humans. The natural concentration of such metals in surface water is exceedingly small, but concentrations are increased along the food chain until toxic levels can destroy certain species. For instance, populations of shell fish have been eliminated in some areas, and there have been cases of brain damage, birth defects and death to human beings attributed to "biomagnification" of some heavy metals.

When heavy metals are discharged into municipal sewage treatment plants, there is some danger of direct toxicity to essential bacteria. Normally, the heavy metals concentrate in the sludge produced. This sludge can be toxic to some plants if applied to land, or toxic to marine life if dumped at sea.

Much more is to be learned about the delayed effects of heavy metal discharge. It is evident, however, that the discharges should be minimized.

2. What industries or operations typically discharge these metals?

The plant waste streams of metal plating and finishing operations, certain textile, dye and pigment operations, mercury cell operations, metal fabricators, smelting and ore handling operations and cooling tower blowdown usually contain one or more of these toxic metals.

3. What do the regulations call for?

Federal regulations require the "best practical technology" to be applied by 1977, and "the best available technology" to be applied by 1983. The discharge permit system, as administered in different geographical locations, may set more specific requirements, and any local regulatory agency can set more stringent demands but not less stringent demands than the federal government.

Discharges going into a municipal treatment system may have different limitations than discharges into surface water.

It is wise to determine the local regulations before action is taken.

4. What has previously been considered the "best practical technology" for treating waste containing heavy metals?

In many cases, mixtures of these heavy metals have been treated by pH adjustment with either lime or caustic soda to cause precipitation of metal hydroxide sludge. This is sometimes called "Lime and Settle" process or the hydroxide process.

Chromium presents a special problem when it is present as a chromate, or in its hexavalent state. It first must be reduced to the trivalent state before it can be precipitated as a hydroxide. The reduction step commonly is carried out at a pH of about 2 with a reducing agent such as sulfur dioxide gas, sodium metabisulfite, or ferrous sulfate. When the reduction is complete, the pH must be raised to allow the chrome hydroxide to form. Therefore, hexavalent chrome wastes are normally isolated from other wastes and treated separately.

5. Are there any problems or inadequacies with the hydroxide process?

Yes, the hydroxide process is often not capable of removing enough of the heavy metal contaminants to achieve specified discharge levels. There are a number of reasons for this.

(a) A metal such as zinc reaches a minimum solubility at a specific pH, and further additons of hydroxide can cause the zinc to become more soluble. Trivalent chrome behaves the same way, but requires a different pH to achieve minimum solubility. When there is a mixture of these metals it is not possible to precipitate them both to low levels. The following graph (published by the EPA) illustrates this relationship.
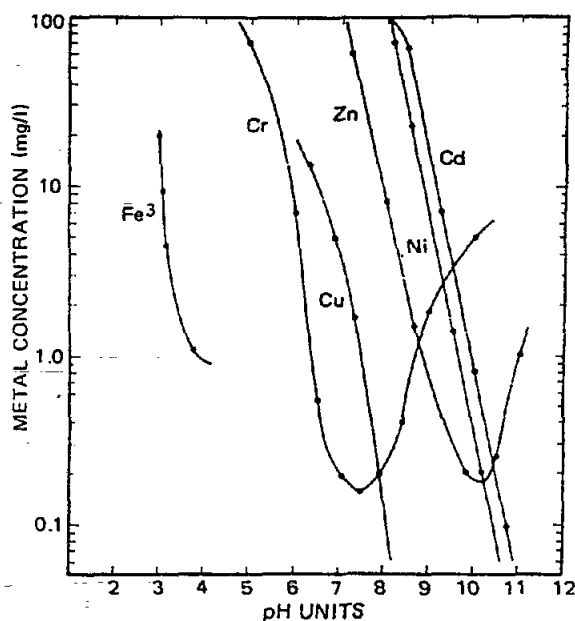
Precipitation of metal salts versus pH

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(b) It has also been found that materials such as oils and grease, soaps or other organics, can interfere with the separation of the hydroxide precipitate from the water effluent.

(c) Particularly important, chelating or complexing agents, which tend to prevent precipitation of the hydroxides, sometimes are present in the waste water.

Another problem is that some metals require a very high pH to precipitate as hydroxide to low levels; the effluent water must then be neutralized before it can meet discharge pH limitations.

6. What are the chelating or complexing agents and how do we know if they are present?

Materials such as "EDTA", gluconates, ammonia complexes, Rochelle salts, etc., are often added to plating solutions to keep the heavy metals in solutions. In many cases, when plating operators purchase proprietary solutions from suppliers, the chemical compositions are not provided. An analysis may be made for a total organic carbon or ammonia to indicate whether or not such materials are present, but normally it is necessary to experimentally determine how completely the metals are precipitated.

7. Are the metal sulfides a great deal less soluble than the metal hydroxides?

Yes, as can be seen from the following table.

Approximate Solubilities of Metals
ppm in pure water

Metal	As Hydroxide	As Sulfide	Factor *
Iron	5×10^1	1×10^{-4}	5×10^3
Zinc	3×10^2	1×10^{-6}	3×10^8
Cadmium	3×10^0	1×10^{-8}	3×10^8
Nickel	7×10^{-1}	6×10^{-8}	1×10^7
Copper	2×10^{-2}	2×10^{-13}	1×10^{11}
Lead	2×10^0	6×10^{-9}	3×10^8
Mercury	6×10^{-4}	1×10^{-21}	6×10^{17}
Silver	2×10^1	4×10^{-12}	5×10^{12}
Chromium	1×10^{-3}	(No Precip)	

$$*Factor = \frac{Solubility\ as\ Hydroxide}{Solubility\ as\ Sulfide}$$

Ksp data from 11th edition of Lange's Handbook was used to calculate solubilities.

8 Why has sulfide precipitation of heavy metals not been favored over hydroxide precipitation?

Because, as a practical matter, most waste water streams are subject to variations in both flow rates and metal concentrations, and there is no practical way to add the exact amount of soluble sulfide to correspond to the metal to be precipitated. If too little is added, all the metal will not be precipitated. If too much is added, the excess sulfide will be in the water effluent, and there can be a problem with the evolution of H₂S gas which has an objectionable odor and can be toxic above certain concentrations.

9 How does the Permutit Sulfex Process overcome this problem of supplying a sufficient amount of sulfide without allowing excess sulfide to discharge with the water or into the air?

It turns out to be relatively simple, involving the solubility and chemistry of iron sulfide. Knowing the expected flow rate of the heavy metal to be precipitated, an excess amount of sulfide is provided so that under normal conditions, all of the heavy metal can be converted to a sulfide. Iron is also provided in a quantity so that all of the sulfide added can be precipitated as iron sulfide. To the extent that there is any excess

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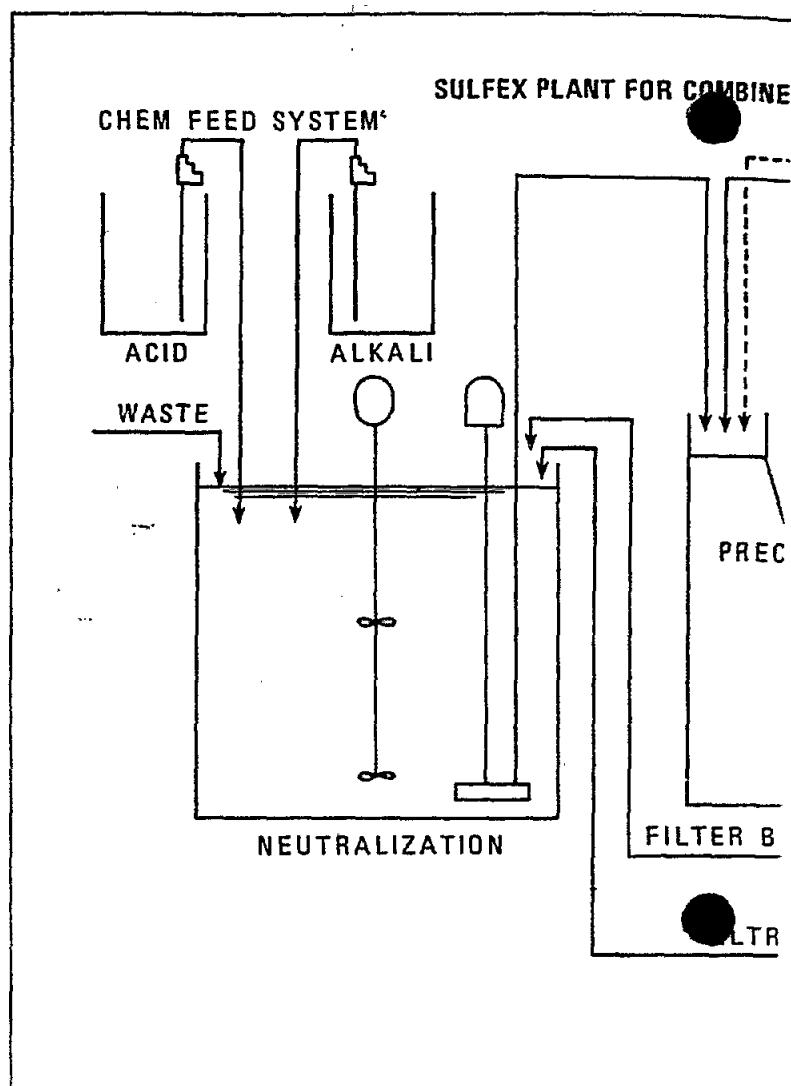
iron in the system, this is precipitated as iron hydroxide by maintaining the pH usually in the 8 - 9 range. Under these conditions, there is no significant discharge of soluble sulfide or iron with the water effluent and no detectable odor of H₂S.

If there is a temporary increase in the amount of heavy metal running into the treatment system, so that the heavy metal requires more sulfide than the amount being added, sulfide will be withdrawn from excess iron sulfide sludge maintained in the system.

In practice, the sulfide normally is added as a freshly made iron sulfide precipitate, which in some respects can be compared with a disposable ion exchange resin to extract soluble heavy metals from the waste water. It is not necessary to match the addition rate of the iron sulfide exactly with the flow rate of heavy metals so long as some excess iron sulfide and iron hydroxide is normally removed with the sludge.
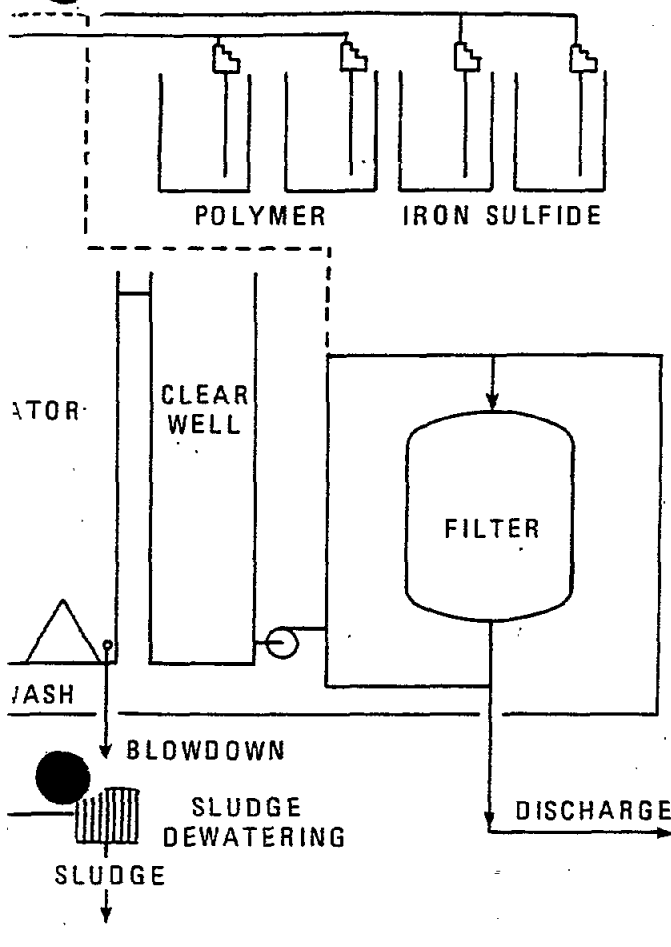
10. How is the capture of the very small or near colloidal precipitates controlled in the Permutit Sulfex Process?

Generally the well demonstrated Permutit Precipitator sludge blanket clarifier is used to continuously remove suspended and near-colloidal particles from the raw water.

For low flow rates, another type of filter may be selected.

A polishing filter often is specified to give further assurance that the effluent is sparkling clear and free of visible solids.

The Permutit Company, Inc., has a great deal of practical experience in removing suspended solids and near-colloidal materials from raw water and waste water. This experience forms an important basis for the Permutit Sulfex Process.

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MOVAL OF HEAVY METALS

POLYMER   IRON SULFIDE

CLEAR WELL

\TOR·

FILTER

/ASH

BLOWDOWN

SLUDGE DEWATERING

DISCHARGE

SLUDGE

11. What levels of heavy metal removal have been achieved· using the Permutit Sulfex Process?

Levels under 0.05 ppm have been achieved for all heavy metals. and levels down to ppb with some. It should be noted that there are several variables at work affecting the extent of metal removal. including the presence of chelating agents.

12. Are all chelating agents equally troublesome?

No. the low solubility of the metal sulfides can overwhelm the presence of most commonly used chelating agents, but not all metals respond the same. In some tests, sulfide precipitated copper in the presence of ammonium. succinate, pyrophosphate. acetate, and Rochelle salts to levels of 0.01 - 0.02 ppm. Under comparable conditions with citrate, the level was 0.66 ppm and with EDTA it was 1.7 ppm. However. with more efficient contact with iron sulfide solids, the effluent level was maintained under 0.1 ppm. even in the presence of EDTA.

**13. How do such numbers compare with levels achievable by the hydroxide process?**

Under the comparative test conditions above. the copper was 3 ppm with citrate and 2.6 ppm with EDTA and 0.16 ppm with pyrophosphate. In general, the levels achieved by sulfide precipitation are lower than the levels achieved by hydroxide precipitation.

The most dramatic difference occurs when hexavalent chrome is in the waste water. In this case the hydroxide process fails completely to remove chrome. The sulfide process typically gave test levels of chrome under 0.05 ppm. Even when EDTA was also present, the chromium was reduced to 0.1 ppm or less.

14. How does the Permutit Sulfex process work so well when the chromium is initially present as a chromate in the hexavalent condition?

The Sulfex reagent, iron sulfide, has the ability to reduce hexavalent chrome by the following reaction:

$$CrO_4^= + FeS + 4 H_2O \rightarrow Fe(OH)_3 + Cr(OH)_3 + S^\circ + 2 OH^-$$
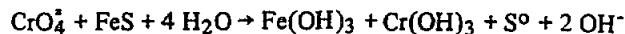
Note that chromium precipitates as the hydroxide rather than the sulfide.

15. Does this mean that the chromate bearing solutions do not have to be isolated and treated separately when the Sulfex process is used?

Yes.

16. What kind of guarantee will Permutit make regarding its Sulfex Process?

Permutit will guarantee the chemistry of the process, and the workability of the equipment supplied, based on certain input conditions as agreed upon, but obviously, Permutit cannot be responsible for the day-to-day operation of the equipment in a fashion to meet quantitative limits that may be imposed by regulatory agencies. Where there is any question regarding the presence of chelating agents, or other organics that might interfere with the process. laboratory tests and in some cases pilot plant tests are recommended.

17. Is there a charge for laboratory tests or a pilot plant?

Yes. Permutit charges a nominal fee for a laboratory study and a rental fee for pilot plant equipment. Usually. if equipment is subsequently purchased the charges for a laboratory study or pilot study will be refunded.

18. What is the cost and the availability of the chemicals required?

The iron sulfide slurry used in the Permutit Sulfex Process is normally made from ferrous sulfate. a soluble sulfide. and lime. The quantities needed are relatively small compared to their great availability. Either sodium hydrosulfide or sodium sulfide. and either lime or sodium hydroxide may be purchased. Costs should be established through local chemical suppliers.

19. How does the cost of operating the Permutit Sulfex Process compare with the cost of operating hydroxide process?

The cost of the chemicals can be significantly less for the Sulfex Process under certain conditions. For instance, where hexavalent chrome must be treated, the simplicity of the one-step operation is much better than the alternative of sequentially using acid. sulfur dioxide. and lime.

The cost of operating the hydroxide process depends both on the total water flow and the metal concentration. In many cases. a great deal of lime is required simply to achieve the high pH, after which acid must be added to reduce the pH to an acceptable level for discharge. Note that where one unit of hydroxide is required to change the pH from 7 to 8, 1,000 units are required to achieve a pH of 11.

In both the hydroxide process and the Permutit Sulfex Process, comparable facilities are needed to add the reactant chemicals, and separate the resulting sludge.

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20. What about sludge disposal from the Permutit Sulfex Process?

The sludge produced is a mixture of metal sulfides and hydroxides in a flocculated, dewaterable condition. The metal sulfides are very insoluble, and chemically equivalent to many of the naturally occurring metal ores that comprise part of the land mass. However, it is recommended that the sludges should be disposed of where they will not be washed into surface water or contacted with inorganic acids. A land-fill disposal site is normally preferred. Permutit also supplies sludge dewatering equipment.

21. Can heavy metals be recovered from the sulfide sludge?

In some cases, this probably could be justified. However, the Permutit Company has not been involved in this.

22. If a plant has existing facilities for operating the hydroxide process, can they be converted to handle the Permutit Sulfex Process?

In many cases, yes. There are options of utilizing available equipment for the Sulfex Process, or alternatively to add new facilities for the Sulfex Process to treat the effluent from the hydroxide process. Each case should be considered separately.

23. Are there any patent royalty charges relative to the Permutit Sulfex Process?

Yes, but Permutit is primarily interested in selling the specialized equipment related to the Permutit Company experience. However, a royalty charge has been established which is intended to be relatively small compared to the advantages of the Sulfex Process.

24. What are the royalty charges?

For low flow rates, there is a minimum charge currently set at $365 per year. For higher flow rates, where continuous flow equipment would normally be used, the annual charge is computed from the design flow basis. The cost diminishes from about $0.10/1,000 gal. at 25 gpm to under $0.02/1,000 gal. at high flow rates, as determined by an exponential equation. Consult your product specialist for the exact charge.

25. Please review the benefits of Sulfex Process.

Performance: The metal residuals in the effluent are normally lower than can be obtained by the hydroxide process, due to the lower solubility of the metal sulfides and the better ability to overcome most of the chelating or complexing agents.

Cost: The chemical cost may be significantly less, depending on the quantity and types of metal or metals to be treated. This is because hexavalent chrome can be reduced and removed in one step along with other metals and it does not have to be segregated for reduction pretreatment. Also, because sulfides can be precipitated in the pH range of 8-9, it is not necessary to purchase additional lime to achieve the higher pH's required for hydroxide precipitations and additional acid to lower the pH of the liquid effluent before discharge.

26. Are there any disadvantages to the Sulfex Process?

Care must be taken to prevent acids and the sulfides from combining with the release of H_2S, but it is not difficult to maintain this care and prevent odor emission.

Also, since the process is more effective than hydroxide systems, the total weight of sludge to be disposed of is greater, but where wasteful quantities of heavy metal are not being discharged to the sewer, the total amount of sludge produced is relatively unimportant.

27. What if there are cyanides present in the waste stream?

The Sulfex Process is strictly a heavy metal removal system. Any cyanides must be oxidized in a pretreatment step before they are introduced to the sulfex reaction. The Permutit Company can furnish the cyanide destruct system.

28. If new regulations are put into effect requiring a still lower level of discharge, or a "zero discharge", will the Sulfex Process be obsolete?

No. After the heavy metals have been removed by the Sulfex Process, the effluent can be further treated by ion exchange to remove soluble salts, or, treated by reverse osmosis facilities to produce a water which can be recycled within the operation.

29. What data should be collected to allow a proposal to be made for a Permutit Sulfex Process?

1. Nature of the business that generates the waste water.
2. The hours the plant operates per-day. The days the plant operates per-week.
3. List the various process lines and if possible provide a simple flow sketch of them.
4. List the average flow rates of rinse waters from each process line. Provide best possible estimate of the maximum flow the system must handle.
5. How many dump tanks does plant have? What is the volume of each tank? What is the dump frequency for each tank?
6. Include analyses of all rinse waters and dump tanks showing concentrations of all metals which must be removed. Dump tank analyses should be representative of the composition at time of dump or plant should extrapolate present analytical data to represent composition at time of dump.
7. If oil or soap is present in waste waters, this information should be included with relevant analyses.
8. Are chelating agents present? How much? What kind?
9. Will plant management submit design data to environmental authorities or have this data submitted by an outside consultant?
10. Effluent quality requirements will vary depending on where treated waste is discharged. If discharge is to a city sewer be sure to check with the city authorities. If discharge is directly to a river or stream, check with state authorities. What are the allowable effluent quality standards for the plant's wastes?
11. If treated waste water is to be recycled, what quality water is required? (Specifically the permissible dissolved solids content).
12. All waste treatment systems must be designed to "fail safe". In this respect transfer pumps, sump pumps, chemical feed pumps and mixers can be critical items. Repair or maintenance of this equipment should be considered because the treatment system can not function unless all pumps and mixers are operating. Does user plan to shut plant down for maintenance? Does user want all pumps duplicated or does user prefer to stock spare equipment?

30. Are there any further questions?

We know that we did not answer all your questions. Permutit specialists in the Sulfex process are available to you for technical assistance on the application and design of treatment systems. Installation lists and performance data from operating Sulfex plants serving a full range of plating waste treatment applications are available.

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